REPORT NUMBER 167

APRIL 1966

GROUND VIBRATION TEST RESULTS

XV-5A

LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT NUMBER DA44-177-TC-715

GENERAL ELECTRIC

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XV-5A Lift Fan Flight Research Aircraft

Contract No. DA44-177-TC-715

April, 1966

ADVANCED TECHNOLOGY AND DEMONSTRATOR PROGRAMS DEPARTMENT
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

FC # 34582

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1.0 SUMMARY

The U.S. Army XV-5A Lift Fan Research Aircraft was subjected to ground tests in the summer and fall of 1963 for evaluation of aircraft characteristics complementary to the flutter and vibration analyses conducted on the XV-5A aircraft. In general, the outline as presented in Reference 1 "Ground Resonance Test Plan, U.S. Army XV-5A Lift Fan Research Aircraft" was followed with several items omitted due to time restrictions.

The basic item, that of the airplane ground vibration test, was completed in late 1963 and these results are summarized below. The configuration of the XV-5A aircraft tested represented the aircraft in its conventional flight mode with a gross weight of approximately 9,700 pounds (c.g. at F.S. 243.5). Both symmetric and antisymmetric modes of the aircraft were determined. Although the modes have been classified as airplane normal modes, each mode exhibits a predominant motion of one or more aircraft components i.e. wing, fuselage, horizontal and vertical stabilizers and control surfaces.

SYMMETRIC AIRPLANE MODES

MODE NO.	FREQUENCY (cps)	DAMPING (g)	PREDOMINANT MODAL CHARACTERISTIC
1	11.2	0.040	Wing Bending
2	14.1	0.044	1st Fuselage Bending
3	21.4	0.106	2nd Fuselage Bending
4	29.4	0.124	Wing and Fan Mode
5	31.3	0.031	Horizontal Stabilizer Bending
6	36.3	0.037	Aileron Rotation
7	44.7	0.068	Wing Torsion
8	55.9	0.033	Horizontal Stab. Pitch and Torsion
9	67.8	0.031	Higher Wing Mode
10	90.3	0.031	Elevator Bending

ANTISYMMETRIC AIRPLANE MODES

MODE NO.	FREQUENCY (cps)	DAMPING (g)	PREDOMINANT MODAL CHARACTERISTIC
1	8.8	0.030	Vertical Stabilizer Bending
2	11.9	0.045	Horizontal Stabilizer Yaw-Vertical Stabilizer Torsion

ANTISYMMETRIC AIRPLANE MODES (Continued)

MODE NO.	FREQUENCY (cps)	DAMPING (g)	PREDOMINANT MODAL CHARACTERISTIC
3	14.5	0.023	Horizontal Stabilizer Roll - 1st Fuselage Bending
4	18.5	0.046	Wing Bending
5	23.0	0.019	2nd Fuselage Bending
6	25.3	0.046	Fuselage Torsion
7	34.8	0.040	Fuselage Torsion (Forebody)
8	36.8	0.058	Aileron Rotation
9	44.6	0.063	Wing Torsion
10	50.6	0.033	Rudder Bending - Fuselage Torsion
11	72.9	0.025	Horizontal Stabilizer Torsion

2.0 INTRODUCT

This report contains the results of t mental investigation of the static and dynamic characteristics of e U.S. Army XV-5A Lift Fan Research Aircraft as pertaining to the flutter and vibration effort on the XV-5A aircraft. The general arrangement of the aircraft tested is shown in Figure 1. The XV-5A is a V/STOL aircraft designed for research flight testing of the General Electric X353-5 Lift Fan Propulsion System.

The report is divided into three basic parts plus an addendum; the basic parts following in general the test plan as outlined in Reference 1, (i.e., Airplane Resonances, Component Resonances and Component Static tests) while the addendum presents the results, in terms of airplane resonances (normal modes) of structural modifications to the empennage required for flutter prevention. The modes presented in the addendum are representative of the current aircraft and thereby void their equivalents presented in the main body of the report. All the other modes presented were not affected by the structural change and therefore are representative of the current aircraft.

The aircraft considered for the airplane resonant test phase was Aircraft No. 2, S/N 506 in its design gross weight condition of approximately 9,700 pounds (partial fuel). The dynamic system was in essence a free-free aircraft with control surfaces free, but with cockpit controls locked in neutral (aileron flight tabs and rudder trim tab were locked to their respective parent surface).

Components considered for the second phase of the testing were all of the control surfaces (conventional flight mode), wing fan doors, pitch fan doors, wing flaps and thrust spoilers. These latter items were tested as installed on the aircraft (No. 1 aircraft, S/N 505) whereas the testing of the horizontal stabilizer was limited to a jig-mounted stabilizer with a simulated pivotal joint.

Static testing, i.e., free play and rotational stiffness tests, were confined to the horizontal stabilizer mounted in the above mentioned jig.

Evaluation of structural modifications to the empennage (presented in the addendum) was conducted on Aircraft No. 1, S/N 505 for the same aircraft configuration as for the basic airplane resonant test, with the exception of the suspension system for which in the latter tests were the actual landing gear with partially deflected tires and locked nose wheel struts.

3.0 AIRPLANE RESONANCE TEST

The initial ground vibration test of the XV-5A aircraft was conducted at the Ryan Aeronautical Company's plant, San Diego, California during the period of 30 September, 1963 to 27 October, 1963.

3.1 TEST CONFIGURATION

The aircraft configuration consisted of a complete aircraft (No. 2, S/N 62-4506), fueled for a gross weight condition of 9,700 pounds with a c.g. location of F.S. 243.5. All flight instrumentation was either installed or simulated by dummy weights as was pilot simulation. Electrical power and hydraulic system power were supplied by external means. The aircraft was aligned in a level flight attitude simulating the CTOL mode, with all controls locked in neutral by means of the appropriate cockpit control. The aircraft was in a clean state, i.e. all other auxiliary devices such as flaps, thrust spoilers, wing fan louvers, etc. were fully retracted. Wing and pitch lift fans were blocked to their stator blades by means of shock cord for the initial test.

The airplane was suspended to simulate a free-flight condition by means of spring-mounted platforms at the main and nose gear CTOL positions. Figure 2 shows the airplane on its suspension system undergoing final preparation before commencement of testing, whereas Figure 3 presents details of the airplane suspension system.

3.2 TEST EQUIPMENT AND INSTRUMENTATION

Excitation of the aircraft was provided by eight electromagnetic shakers mounted at various locations on the aircraft as shown in Figure 4. Various combinations of shakers, up to the maximum of eight, were used for modal surveys as will be discussed later. Resonant frequencies and modal surveys were established from the recorded output of accelerometers located throughout the aircraft, the pickup locations being shown in Figures 5 & 6 for the symmetric and antisymmetric test phase of the airplane resonance test. Control surface motion was detected by means of strain-gaged beams in addition to accelerometer outputs. Figures 7 through 9 present the location of the control surface points at which measurements were taken, while Figures 5 and 6 show the location of the strain-gaged beams. Table 1 lists the test equipment and instrumentation utilized in the test.

3.3 GENERAL TEST PROCEDURE

Both symmetric and antisymmetric resonances were investigated in a similar manner and differed only by the sense of application of shaker forces. The resonant frequencies of the aircraft were established from the recorded output of certain fixed accelerometers as indicated in Figures 5 and 6. These resonant frequencies were selected on the basis of response studies of various shaker combinations under different force inputs. Frequency sweeps for each main component of the aircraft (i.e. wing, fuselage, horizontal and vertical stabilizers) were made under different loading conditions. The response of the aircraft from one of the fixed accelerometers at one of the drive points plus selected accelerometer outputs from the fuselage and horizontal stabilizer in the case of a symmetric sweep and wing excitation and from the horizontal and vertical stabilizers in the case of antisymmetric sweeps and wing excitation, were utilized in establishing the resonant conditions. Table 2 lists the shaker combinations and selected accelerometer outputs displayed on the response plot (X-Y recorders). Establishment of the airplane resonant frequencies was through a study of the abovementioned response plots, deliberate tuning to the particular mode with the best shaker combination for that component, as shown by the response, study of the decay characteristics of the structure upon excitation cutoff and visual monitoring of the mode. Having established the resonances, tuning to a particular resonance for modal surveys attempted to follow the procedure as discussed in Reference 2. Although not followed completely, the technique of observing force-velocity phasing (through caliberated strain-gaged links between aircraft and shaker coil) as discussed in Reference 2, allowed utilization of available exciters. The mode shapes for the particular resonant condition were established by utilizing a battery of roving pickups (accelerometers) with measurements made at the pickup locations as shown in Figures 5 through 9. In addition to measurements taken at these points, measurements of suspension system platforms in the coordinate directions were also made. Measurements were recorded in terms of voltages with phasing, with reference to a master pickup determined from oscilloscopes. In addition to these readings, oscillograph recordings were made for each measurement for damping and frequency determination, in addition to the post-vibration-test scanning of doubtful areas.

3.4 RESULTS AND CONCLUSIONS

Initial testing of the airplane on its suspension system yielded the following airplane rigid body modes:

Vertical Translation	2.2 cps
Side Translation	1.9 cps

Fore and Aft Translation	0.7 cps
Pitch	1.7 cps
Roll	2.2 cps
Yaw	0.7 cps

Excitation for the above modes was by shaker or hand - forcing with response monitored by accelerometers (Statham) located at several points on the aircraft.

Following establishment of the resonant frequencies for both the symmetric and antisymmetric case, complete modal surveys of the aircraft were made utilizing a battery of roving accelerometers (Endevco) as mentioned previously. Examination of the resulting mode shapes, when plotted against major structural elements, (for example, deflection along the wing rear spar versus butt-line) indicated inconsistencies among data points in a number of cases. Assuming errors in voltmeter readings, the oscillograph recordings were reduced to reflect the deflection relative to the voltage reading at a reference point and plotted. To determine the final mode shape, the individual plots, if necessary, were smoothed by the method of least squares utilizing best fit data (voltmeter or oscillograph readings). The smoothed plot was then further scrutinized for continuity at major structural intersections and refitted or faired, if necessary, to obtain continuity. A major reason for inconsistencies among mode shapes was the inability of maintaining calibration among the battery of five accelerometers used for modal surveys. Preliminary node line sketches, taken during mode set-up, aided in establishing the deflection shapes of each mode.

A summary of the resonant frequencies and the predominant nature of the mode is given in Table 3. The normalized displacements of the symmetric modes are presented in Tables 4 through 13 and are shown in pictorial form in figures 10 through 19. The fuselage readings for the antisymmetric case were reduced to reflect the linear and angular displacements about W. L. 100. Similar results for the antisymmetric modes are shown in Tables 14 through 24 and in Figures 20 through 30. Structural damping coefficients (g) for each mode are also presented in Table 3, with these values determined from the modal decay oscillograph recording of the dominant pickup location for the predominant component of the airplane.

The predominant modes of interest in an analysis of the empennage, the critical aspect of the XV-5A aircraft with respect to a flutter analysis, would be Modes 1, 2, 3, 4, 5, 8 and 10, symmetric. Although several of these modes have been classified as predominant wing or fuselage modes, the response of the empennage (horizontal tail) in these modes is significant enough to be included in an analysis. Modes 5 and 8 are the

basic elastic modes of the horizontal stabilizer, with Mode 8 being coupled pitch-torsion. There was no evidence of a pure pitch mode existing, a fact established previously, (see Section 4.0).

For the antisymmetric case, the modes of interest to an empennage analysis would be Modes 1, 2, 3, 5, 6, 10 and 11. The horizontal tail rigid body modes of yaw and roll are pronounced, as evidenced in the pictorial views of Figures 21 and 22. Horizontal tail pitch no longer appears, due to the symmetric nature of this mode. Vertical stabilizer torsion is evident in Mode 2, but is highly coupled with the fuselage and the effects of the horizontal tail yaw. The node line is evidenced by Figure 21, (although not drawn), runs up the vertical stabilizer and is swept back through the trailing edge of the stabilizer, due to the elastic effects of the fuselage.

4.0 COMPONENT RESONANCE TEST

With the establishment of the basic airplane vibration modes, emphasis was then placed upon determining the vibration characteristics of miscellaneous components of the aircraft i.e. lateral, longitudinal and directional control systems (CTOL mode), flaps, wing fan doors, pitch fan doors and thrust spoiler. Separate resonance testing of the jig-mounted horizontal stabilizer was performed to determine rigid body modes about the pivotal joint. The former test period extended from 18 November, 1963 to 25 November, 1963, whereas the latter preceded the ground vibration testing of the complete aircraft and covered the period of from 7 September, 1963 to 9 September, 1963.

4.1 TEST CONFIGURATIONS

The test configurations, so employed in the component resonance test, may be conveniently grouped into three categories, mainly primary control systems, horizontal stabilizer and finally miscellaneous components.

4.1.1 Primary Control Systems

In order to provide meaningful data for eventual incorporation into future analytical flutter analyses, the test configuration of the aileron, elevator and rudder systems were so arranged to provide both a stick-free and stick-fixed system with the locking out by external means of any control surf surface or tab degree of freedom as the case warranted. Since the primary objects of these tests were systems, and not airframe, the airplane was placed upon its jacks to provide additional restraints. The aircraft tested for this phase was the No. 1 aircraft, S/N 505, which was in a partial state of completion at the time of testing. Electrical power and hydraulic system power were supplied by external means.

4.1.2 Horizontal Stabilizer

Since the sole objective of the horizontal stabilizer test was to determine its rigid body viluatory characteristics, the test configuration used was the complete stabilizer (with a simulated pivotal joint) from the No. 2 (S/N 62-506) aircraft mounted on a rigid test stand. A flight pitch actuator was used and the pivot and actuator attach fittings on the test stand were manufactured with identical tolerances with the flight hardware. The pitch

actuator, being a mechanical jackscrew, driven by hydraulic motors, was preset in the desired postion mechanically and thereby no external means of power was required for these tests.

4.1.3 Miscellaneous Components

Test configurations of the flaps, wing fan doors, pitch fan doors and thrust spoiler were the actual items as installed on the aircraft, with the same aircraft used as during the primary control systems test.

4.2 TEST EQUIPMENT AND INSTRUMENTATION

Excitation of the aircraft components was provided by one or two, (as the case warranted) electromagnetic shakers mounted either in the cockpit or at an optimum position on the appropriate control or auxiliary device. Excitation of the horizontal stabilizer was by means of two shakers located at various points on the surface to provide the required moment about the pivotal joint, as shown in Figure 4. These locations were designated by the term, "secondary". Resonant frequencies and modal surveys, if any, were established from the recorded output (voltages) of accelerometers (Endevco) which were located at strategic points on the components. Figures 7 through 9 present the locations of the control surface points which were used for the tests, while Figures 31 through 34 present the locations of pick-up points on the flap, wing fan door, pitch fan door and thrust spoiler. Horizontal stabilizer locations are shown in Figures 5 and 6 with the appropriate points used as per sense of excitation.

4.3 TEST PROCEDURE

In general, the test procedure used in determining the component resonances was similar to that performed on the basic airplane vibration test. Initial frequency sweeps were made of the particular system or component under investigation. The resonances were noted from the resulting response plot and visual observation, manually tuning to these resonances for sharper definition and finally, modal surveys made, if needed by the roving pickup technique with a pair of accelerometers (Endevco), one being used as a reference and one as the roving transducer. Upon completion of the survey, oscillograph records were taken for frequency and damping determination.

4.4 RESULTS AND CONCLUSIONS

Since the rigid body modes were the primary objectives of this phase of testing, no pictorial views are presented.

The primary control systems' resonance test yielded partial results, due to difficulties encountered in modal coupling with the airframe proper. Additional restraints, other than aircraft jacks, proved to be impractical. Therefore, only those vibration modes which were felt to be indicative of the control systems are recorded herein. Table 25 presents the results of this phase of the component resonance testing. As can be seen from the results, the aileron system and elevator system tests proved to be more fruitful than the rudder system tests. This ties in with the manner in which the aircraft is supported by jacks; the two on the wings plus the fuselage jack at location F-8 provided the additional vertical restraint needed for excitation in the vertical sense, whereas excitation in the horizontal plane as in the case of rudder system, brought into play the lateral flexibility of the fuselage and vertical stabilizer. Isolation of the aileron flight tab uncoupled rotational mode proved to be an impossibility, since the only restraint provided for the aileron itself was the hydraulic actuator which provided only a point fixity.

Determination of the miscellaneous components was relatively simple and the results of these tests are presented in Table 26.

Establishment of the rigid body modes of the horizontal stabilizer yielded only one, or at the best, two valid frequencies, that of yaw and roll. The yaw mode was 12.9 cycles per second and could be considered representative of the actual case, whereas the roll mode was determined to be 16.85 cycles per second. Investigation of jig motion revealed that a small percentage of coupling was apparent between jig and stabilizer. Comparison of these modes with those presented in Section 3.0 shows 11.9 cycles per second, yaw versus 12.9 cycles per second and 14.5 cycles per second, roll versus 16.85 cycles per second. Comparison is good when considering the nature of the test, i.e. jig-mounted horizontal versus actual aircraft shake, wherein modal coupling is more pronounced, due to vertical stabilizer and fuselage effects. In any event, these modes were considered for inertia correlation, as will be discussed in Section 5.0. Isolation of the pitch mode, particular to the effects of simulation, was impossible, due to coupling with the elastic modes of the horizontal stabilizer. The following modes were noted for interpretive purposes:

Bending - Pitch	24.7 cps
Pitch - Bending - Torsion	42.1 cps
Pitch - Torsion - Bending	50.8 cps

Examination of these modes with those determined from the airplane resonance test, and the frequency determined from the static tests (Section 5.0) verified the inability of determining the true uncoupled pitch mode.

5.0 COMPONENT STATIC TEST

Static testing of components of the XV-5A aircraft for flutter and vibtation correlation was restricted entirely to determination of the effective spring rates (about coordinate axes) of the three degrees of freedom associated with the rigid body motion of the horizontal stabilizer. This test was conducted jointly with the resonance testing of the horizontal stabilizer, as discussed in Section 4.0, and covered the period of from 7 September, 1963 to 9 September, 1963 and also 17 March 1964.

5.1 TEST CONFIGURATION

The test configuration, employed for this phase was the complete horizontal tail from the No. 2 (S/N 506) aircraft for the yaw and roll investigations, whereas the No. 1 (S/N 505) horizontal stabilizer (less elevators) was used for the pitch tests. Mounting was separate from the aircraft and employed the same fixture as described in Section 4.0 with the actual actuator installed.

5.2 TEST EQUIPMENT AND INSTRUMENTATION

In each phase of the testing of the horizontal stabilizer, loads were applied to the horizontal stabilizer through a loading jig that enclosed the rib at BL 70.16 on both ends of the stabilizer. An additional pair of loading jigs at BL 16.56 was used in the pitch test. A pulley system was used to obtain the proper load direction, and 20 or 25-pound shot bags placed upon load pans provided the applied torque in the appropriate direction.

Dial gages located at selected points on the surface were used to measure deflection. In addition, small mirrors, reflecting a cross-hair image from a light source onto a calibrated screen, were used to measure change of slope. Schematics of the pitch, roll and yaw loading and instrumentation set-ups are shown in Figures 35 through 37, whereas Figure 38 depicts a photo of the test set-up for the pitch phase.

5.3 TEST PROCEDURE

The test procedure to determine effective restraints was simply orientation of the loading jig and dial gages and/or mirrors for proper axis definition, with the load being applied in incremental parts with deflection and/or

slope information being simultaneously measured. A complete load cycle gave data on both sides of the free-play regime, enabling the spring rates and free-play to be determined.

5.4 RESULTS AND CONCLUSIONS

Interpretation of effective spring rates as obtained from these series of tests was somewhat difficult, since it was not known to what extent local back-up structure in the vertical stabilizer had in the apparent idealization of these effective springs. It was assumed that for the roll and yaw springs, the pivotal joint (which was of the same material and incorporated actual pivot bolts) would yield approximate results valid for analysis purposes.

The pitch spring was apparently misleading, since the effective pitch spring is, in essence, composed of the actuator, pivot fittings, bearings, horizontal stabilizer local back-up structure and also local back-up structure of the vertical stabilizer which was not simulated. Therefore, determination of this spring rate had to be approached with caution.

5.4.1 Pitch Spring

The deflection and load data taken at the locations shown in Figure 35 were reduced and plotted as angular rotation versus applied pitching moment as shown in Figure 39. These data were reduced by treating the root ribs as an overhanging box beam simply supported at the actuator - front spar intersection and horizontal stabilizer pivot. Deflection data for each increment of load taken at dial gages 1 and 2 were averaged, and combined with the average data from gages 3 and 4 to describe the rotation of a plane representative of the elastically - undeformed horizontal stabilizer. Then, computing the angular rotation of the support jig for each increment of load from the deflection data of gages 7 through 11, and subtracting, the net angular rotation in pitch versus applied load was obtained.

Figure 39 shows that the spring rate is non-linear and increases with applied load. This result is reasonable, since the system has a number of bearing contacts where total bearing area increases with load.

The minimum pitch spring rate and the minimum average pitch spring rate determined from the slope of the curves between the first two data points on both sides of the free-play region are:

Minimum Pitch Spring Rate = 9.5×10^6 in-lb./rad.
Minimum Average Pitch Spring Rate = 11.4×10^6 in-lb./rad.

The experimental pitch spring rate used in conjunction with calculated effects of vertical stabilizer was 10.33×10^6 in-lb./rad., with a resulting effective pitch spring rate of 6.09×10^6 in-lb./rad.

Approximately 2,000 inch - pounds of moment (leading edge down) was required to balance the stabilizer in the loading jig. The free play was determined from Figure 39 at this load level to be as follows:

Pitch Free Play = 0.0011 radians

Inability to shake out a rigid body pitch mode resulted in using experimental inertia properties in an attempt to arrive at a value for use in flutter analysis correlation. Swinging of the horizontal tail gave the following results as compared to the calculated value:

$I_{Pivot} = 43{,}085$ lb. - in^2 Experimental

$I_{Pivot} = 34{,}440$ lb. - in.^{2} Calculated

Thus, it can be seen that the calculated value had been underestimated by a factor of 1.25.

Using the minimum projected spring rate of 6.09×10^6 in-lb./rad. in conjunction with the experimental inertia value, the estimated value of the uncoupled pitch frequency was determined to be:

f = 37.2 cycles/second

5.4.2 Roll Spring

The mirror and load data taken at the locations shown in Figure 36 were reduced and plotted as angular rotation versus applied rolling moment as shown in Figure 40. The angular values in the plot were determined by averaging the net roll angle experienced at mirror locations 1 and 2 obtained by subtracting from each the angular rotation at mirror location 3. An average of the slope of the two straight line least square fits of the data for each load direction was considered to be the roll spring rate, and the horizontal distance between their zero load intercepts was considered the the roll free-play. These values are as follows:

Average Roll Rotational Spring Ratio = 11.3×10^6 in. - lb./rad.

Roll Rotational Free-Play = 0.00032 radians

The difficulty inherent in the geometry of the horizontal stabilizer pivot fitting support, wherein the applied rolling moment must be reacted by a couple with only a 6.06 inch moment - arm, created an inpractical test situation. The roll spring is composed of the elasticity present in the pivot fitting, bearings and local back-up structure. Any method of loading this system must produce elastic deformation of the stabilizer surface proper. Therefore, the measurements of slope during the test included any beam deformation of the horizontal stabilizer. In deriving the roll spring rate from the test data, it was assumed that the change in slope of the elastic curve due to deformation of the stabilizer as a beam in the support area was small, compared to the change of slope due to rigid body roll.

Comparision of roll inertias (about BL O and WL 201.75) both calculated from weights information and also from static and frequency measurements yielded the following:

$I_{Roll} = 389,544$ lb. - in.^{2} Experimental

$I_{Roll} = 166,541$ lb. - in.^{2} Calculated

From the above, it can be seen that the calculated value had been underestimated by a factor of 2.34. However, closer examination of the spring rate determination indicated movement of the support jig which also may have been involved in the vibration mode. Consequently, the factor of 2.34 may be somewhat larger than it should be, if jig motion was non-existent during resonance. The test essentially indicates an uncoupled roll frequency of the order of 16 cps and also that calculated inertia values are low. Examination of deflection data taken during the vibration test indicated some small deflection, both in the lateral and vertical sense of the pivot assembly and mounting jig, thereby warranting the above conclusion.

5.4.3 Yaw Spring

The mirror and load data taken at the locations shown in Figure 37 were reduced and plotted as angular rotation versus yawing moment as shown in Figure 41. The angular values in the plot were obtained by subtracting the rotation at mirror 2 from the rotation at mirror 1 for each loading increment. An average slope of the straight line least square fits of the data for each loading direction established the spring rate, and the horizontal distance between their zero load intercepts represented the free-play. These values are as follows:

Average Yaw Rotational Spring Rate = 3.11×10^6 in.-lb./rad.

Yaw Rotational Free-Play = 0.00033 radians

Comparison of yaw inertias (about vertical axis through pivot), calculated from weights information and also from the static and frequency measurements yielded the following:

$I_{Yaw} = 182,919$ lb. - in.^{2}	Experimental
$I_{Yaw} = 194,434$ lb. - in.^{2}	Calculated

From the above, it can be seen that the calculated value had been overestimated by a factor of 0.94. Examination of the deflection measurements taken during the shake test indicates negligible movement of the base (jig) and therefore correlation between the inertias as shown above is considered excellent.

6.0 APPENDIX

REFERENCES

1. Ground Resonance Test Plan, Report Number 128, September, 1963.

2. Lewis, R.C. and Wrisley, D.L.; A System for the Excitation of Pure Natural Modes of Complex Structures, Journal of the Aeronautical Sciences, Volume 19, 1950.

3. Preliminary Flutter Analysis, Volume II - Empennage, Report Number 163, November, 1965.

TABLE 1

TEST EQUIPMENT AND INSTRUMENTATION

Exciter System

1. Calidyne Model 3810 exciter system utilizing eight (8) Calidyne Model D-88 excitors rated at 100 pound vector force.

2. MB Model PT 112537 exciter system utilizing two (2) MB Model C-1-H excitors rated at 50 pound vector force.

3. Hewlett-Packard sweep oscillator Model 202A.

4. Hewlett-Packard frequency counter Model 522.

5. Ryan manufactured strain gaged force rings in conjunction with a CEC Model 1-113 carrier amplifier.

6. Brüel and Kjaer vacuum tube Model 2409 voltmeters.

7. Dumont dual beam Model 304 oscilloscopes.

Instrumentation

1. Endevco Model 2213 crystal-type accelerometers used in conjunction with Endevco Model 2607 amplifiers.

2. Statham Model F-10-350 strain-gage accelerometers used in conjunction with Consolidated Electrodynamics System "D" amplifier/power supply.

3. Minneapolis-Honeywell 12-channel Model 906 oscillograph.

4. Minneapolis-Honeywell 24-channel Model 1508 oscillograph.

5. X-Y plotters.

6. Dumont dual beam Model 304 oscilloscopes.

7. Brüel and Kjaer vacuum tube Model 2409 voltmeter.

8. Khron-Hite variable band-pass Model 330M filters.

TABLE 2

SHAKER AND SELECTED ACCELEROMETER COMBINATIONS
Airplane Resonance Sweeps

Aircraft Component	Sweep Configuration	Shaker Configuration: Shaker Locations Phase				Symmetry	Plotter Component	Plotter Configuration: 1 Wing	2 Fuselage	2 V. T.	3 H. T.
Wing	A	P-1 +			P-2 +	S	Pickup Location	LW-1	F-2	—	LH-1
	B		P-3 +	P-4 +		S		LW-15	F-2	—	LH-1
	C	P-1 +	P-3 +	P-4 +	P-2 +	S		LW-1	F-2	—	LH-1
	D	P-1 +	P-3 —	P-4 —	P-2 +	S		LW-1	F-2	—	LH-1
	J		P-3A +	P-4A +		S		LW-13	F-2	—	LH-1
	K	P-1 +	P-3A +	P-4A +	P-2 +	S		LW-13	F-2	—	LH-1
	L	P-1 +	P-3A —	P-4A —	P-2 +	S		LW-13	F-2	—	LH-1
	X	P-3 +	P-3A —	P-4 +	P-4A —	S		LW-15	F-2	—	LH-1
	M	P-1 +			P-2 —	A/S		LW-1	F-12	—	LH-1
	Q	P-1 +	P-3A —	P-4A +	P-2 —	A/S		LW-1	—	V-10	LH-1
	R	P-1 +	P-3A +	P-4A —	P-2 —	A/S		LW-1	—	V-10	LH-1
	S		P-3A +	P 4A —		A/S		LW-13	—	V-10	LH-1
	T		P-3 +	P-4 —		A/S		LW-15	—	V-10	LH-1
	U	P-1 +	P-3 —	P-4 +	P-2 —	A/S		LW-1	—	V-10	LH-1
	V	P-1 +	P-3 +	P-4 —	P-2 —	A/S		LW-1	—	V-10	LH-1
	C-C	P-3 +	P-3A —	P-4 —	P-4A +	A/S		LW-15	—	V-10	LH-1
Fuselage	E	P-5 +				S		LW-1	F-2	—	LH-1
	F				P-5A +	S		LW-1	F-8	—	LH-1
	H	P-5 +			P-5A +	S		LW-1	F-2	—	LH-1
	I	P-5 +			P-5A —	S		LW-1	F-2	—	LH-1
Horizontal Tail	G	P-6 +			P-7 +	S		LW-1	F-2	—	LH-1
	W	P-6A +			P-7A +	S		LW-1	F-2	—	LH-2

TABLE 2 (Continued)

SHAKER AND SELECTED ACCELEROMETER COMBINATIONS
Airplane Resonance Sweeps

Aircraft Component	Sweep Configuration	Shaker Configuration Shaker Locations Phase				Symmetry	Plotter Component	Plotter Configuration 1 Wing	2 Fuselage	2 V.T.	3 H.T.
Horizontal Vertical Tail	P	P-6 +			P-7 —	A/S	Pickup Location	LW-1	—	V-10	LH-1
	Y		P-8 +			A/S		LW-1	—	V-10	LH-1
	Z			P-9 +		A/S		LW-1	—	V-11	LH-1
	A-A		P-8 +	P-9 +		A/S		LW-1	—	V-11	LH-1
	B-B		P-8 +	P-9 —		A/S		LW-1		V-11	LH-1

TABLE 3

RESULTS OF AIRPLANE RESONANCE TEST

Symmetric

Mode	Frequency cps	g	Table No.	Figure No.	Predominant Modal Characteristic
1	11.2	0.040	4.0	10.0	Wing Bending
2	14.1	0.044	5.0	11.0	1st Fuselage Bending
3	21.4	0.106	6.0	12.0	2nd Fuselage Bending
4	29.4	0.124	7.0	13.0	Wing and Fan Mode
5	31.3	0.031	8.0	14.0	Horizontal Stabilizer Bending
6	36.3	0.037	9.0	15.0	Aileron Rotation
7	44.7	0.068	10.0	16.0	Wing Torsion
8	55.9	0.033	11.0	17.0	Horizontal Stabilizer Pitch & Torsion
9	67.8	0.031	12.0	18.0	Higher Wing Mode
10	90.3	0.031	13.0	19.0	Higher Horizontal Stabilizer Mode

Anti-Symmetric

Mode	Frequency cps	g	Table No.	Figure No.	Predominant Modal Characteristic
1	8.8	0.030	14.0	20.0	Vertical Stabilizer Bending
2	11.9	0.045	15.0	21.0	Horizontal Stabilizer Yaw - Vertical Stabilizer Torsion
3	14.5	0.023	16.0	22.0	Horizontal Stabilizer Roll - 1st Fuselage Bending
4	18.5	0.046	17.0	23.0	Wing Bending
5	23.0	0.019	18.0	24.0	2nd Fuselage Bending
6	25.3	0.046	19.0	25.0	Fuselage Torsion
7	34.8	0.040	20.0	26.0	Fuselage Torsion (Forebody)
8	36.8	0.058	21.0	27.0	Aileron Rotation
9	44.6	0.063	22.0	28.0	Wing Torsion
10	50.6	0.033	23.0	29.0	Rudder Bending - Fuselage Torsion
11	72.9	0.025	24.0	30.0	Horizontal Stabilizer Torsion

TABLE 4

SYMMETRIC MODE SHAPE
MODE 1
f = 11.2 cps g = 0.040

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.6932	LH-1	$\bar{0}.3973$	F-1	$\bar{0}.3086$	LA-1	0.8559	LE-1	$\bar{0}.5386$
LW-2	0.7749	LH-2	$\bar{0}.4715$	F-2	$\bar{0}.2029$	LA-2	1.0000	LE-2	$\bar{0}.6654$
LW-3	0.8935	LH-3	$\bar{0}.3973$	F-3	$\bar{0}.1403$	LA-3	0.7390	LE-3	$\bar{0}.5386$
LW-4	0.5787	LH-4	$\bar{0}.4715$	F-4	$\bar{0}.0909$	LA-4	0.8897	LE-4	$\bar{0}.6654$
LW-5	0.6656	LH-5	$\bar{0}.3973$	F-5	$\bar{0}.0489$	LA-5	0.6329	LE-5	$\bar{0}.5386$
LW-6	0.7447	LH-6	$\bar{0}.4715$	F-6	$\bar{0}.0384$	LA-6	0.7871	LE-6	$\bar{0}.6654$
LW-7	0.4730	LH-7	$\bar{0}.2890$	F-7	$\bar{0}.0677$	LA-7	0.5072	LE-7	$\bar{0}.5386$
LW-8	0.5591	LH-8	$\bar{0}.3973$	F-8	$\bar{0}.1236$	LA-8	0.5760	LE-8	$\bar{0}.6654$
LW-9	0.6076	LH-9	$\bar{0}.4715$	F-9	$\bar{0}.1966$	LA-9	0.4384	LE-9	$\bar{0}.5386$
LW-10	0.3762	LH-10	$\bar{0}.2890$	F-10	$\bar{0}.3663$	LA-10	0.5143	LE-10	$\bar{0}.6654$
LW-11	0.4555	LH-11	$\bar{0}.4715$	Wing Fan		LA-11	0.4008	LE-11	$\bar{0}.5386$
LW-12	0.4821	LH-12	$\bar{0}.2890$	Position	Vert. Defl. + Up	LA-12	0.4753	LE-12	$\bar{0}.6654$
LW-13	0.2901	LH-13	$\bar{0}.4715$						
LW-14	0.3568	LH-19	$\bar{0}.3973$	LWF-1	0.1996				
LW-15	0.3707	LH-20	$\bar{0}.3973$	LWF-2	0.2205				
LW-16	0.1985		F & A Defl. + Aft	LWF-3	0.4125				
LW-17	0.2521			LWF-4	0.1160				
LW-18	0.1198	LH-14	0.3042	Pitch Fan					
LW-19	0.1483	LH-15	0.3042	Position	Vert. Defl. + Up				
LW-20	0.0572	LH-16	0.3042						
LW-21	0.0702	LH-17	0.3042	NF-1	$\bar{0}.2148$				
LW-22	—	LH-18	0.3042						
LW-23	—								

TABLE 5

SYMMETRIC MODE SHAPE

MODE 2

f = 14.1 cps g = 0.044

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.6081	LH-1	0.3405	F-1	0.4412	LA-1	0.7349	LE-1	0.6023
LW-2	0.6772	LH-2	0.5395	F-2	0.1942	LA-2	1.0000	LE-2	0.5581
LW-3	0.6721	LH-3	0.3240	F-3	0.0581	LA-3	0.6442	LE-3	0.5814
LW-4	0.5002	LH-4	0.5019	F-4	$\bar{0}$.0502	LA-4	0.9093	LE-4	0.5465
LW-5	0.5616	LH-5	0.3074	F-5	$\bar{0}$.1093	LA-5	0.5530	LE-5	0.5395
LW-6	0.5588	LH-6	0.4698	F-6	$\bar{0}$.1442	LA-6	0.8209	LE-6	0.5232
LW-7	0.3998	LH-7	0.2209	F-7	$\bar{0}$.1302	LA-7	0.4277	LE-7	0.4953
LW-8	0.4500	LH-8	0.2909	F-8	$\bar{0}$.0486	LA-8	0.6512	LE-8	0.5140
LW-9	0.4516	LH-9	0.4437	F-9	0.0565	LA-9	0.3442	LE-9	0.4465
LW-10	0.3070	LH-10	0.2209	F-10	0.2940	LA-10	0.5651	LE-10	0.4884
LW-11	0.3416	LH-11	0.4237	Wing Fan		LA-11	0.2893	LE-11	0.4326
LW-12	0.3502	LH-12	0.2209	Position	Vert. Defl. + Up	LA-12	0.5186	LE-12	0.4884
LW-13	0.2235	LH-13	0.4072						
LW-14	0.2393	LH-19	0.2837	LWF-1	0.2442				
LW-15	0.2567	LH-20	0.2837	LWF-2	0.3047				
LW-16	0.1333		F & A Defl. + Aft	LWF-3	0.0930				
LW-17	0.1521			LWF-4	$\bar{0}$.1581				
LW-18	0.0547	LH-14	$\bar{0}$.3209	Pitch Fan					
LW-19	0.0581	LH-15	$\bar{0}$.3209	Position	Vert. Defl. + Up				
LW-20	$\bar{0}$.0102	LH-16	$\bar{0}$.3209						
LW-21	$\bar{0}$.0249	LH-17	$\bar{0}$.3209	NF-1	0.2791				
LW-22	—	LH-18	$\bar{0}$.3209						
LW-23	—								

TABLE 6

SYMMETRIC MODE SHAPE
MODE 3
f = 21.4 cps g = 0.106

Wing

Position	Vert. Defl. + Up
LW-1	0.2829
LW-2	0.3855
LW-3	0.4825
LW-4	0.1392
LW-5	0.3128
LW-6	0.3985
LW-7	0.0177
LW-8	0.2502
LW-9	0.3247
LW-10	$\bar{0}$.0729
LW-11	0.1976
LW-12	0.2611
LW-13	$\bar{0}$.1282
LW-14	0.1558
LW-15	0.2087
LW-16	$\bar{0}$.1463
LW-17	0.1589
LW-18	$\bar{0}$.1463
LW-19	0.1238
LW-20	$\bar{0}$.1463
LW-21	.1039
LW-22	—
LW-23	—

Horiz. Stab.

Position	Vert. Defl. + Up
LH-1	$\bar{0}$.4153
LH-2	$\bar{0}$.6638
LH-3	$\bar{0}$.2880
LH-4	$\bar{0}$.4989
LH-5	$\bar{0}$.1939
LH-6	$\bar{0}$.3716
LH-7	0.0427
LH-8	$\bar{0}$.1328
LH-9	$\bar{0}$.2818
LH-10	0.0502
LH-11	$\bar{0}$.2299
LH-12	0.0601
LH-13	$\bar{0}$.2175
LH-19	$\bar{0}$.0928
LH-20	$\bar{0}$.0752

Position	F & A Defl. + Aft
LH-14	0.3117
LH-15	0.3117
LH-16	0.3117
LH-17	0.3117
LH-18	0.3117

Fuselage

Position	Vert. Defl. + Up
F-1	1.0000
F-2	0.3294
F-3	0.0464
F-4	$\bar{0}$.1034
F-5	$\bar{0}$.1463
F-6	0.0840
F-7	0.1702
F-8	0.2144
F-9	0.2100
F-10	0.1105

Wing Fan

Position	Vert. Defl. + Up
LWF-1	$\bar{0}$.2011
LWF-2	$\bar{0}$.2454
LWF-3	0.1039
LWF-4	$\bar{0}$.1083

Pitch Fan

Position	Vert. Defl. + Up
NF-1	0.2277

Aileron

Position	Vert. Defl. + Up
LA-1	0.5128
LA-2	0.8201
LA-3	0.4487
LA-4	0.7515
LA-5	0.3957
LA-6	0.6874
LA-7	0.3205
LA-8	0.6123
LA-9	0.2741
LA-10	0.5614
LA-11	0.2431
LA-12	0.5261

Elevator

Position	Vert. Defl. + Up
LE-1	$\bar{0}$.7140
LE-2	$\bar{0}$.6388
LE-3	$\bar{0}$.6145
LE-4	$\bar{0}$.5504
LE-5	$\bar{0}$.4752
LE-6	$\bar{0}$.4244
LE-7	$\bar{0}$.3890
LE-8	$\bar{0}$.3382
LE-9	$\bar{0}$.3095
LE-10	$\bar{0}$.2431
LE-11	$\bar{0}$.2763
LE-12	$\bar{0}$.1989

TABLE 7

SYMMETRIC MODE SHAPE

MODE 4

$f = 29.4$ cps $g = 0.124$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.3556	LH-1	$\bar{0}.3659$	F-1	$\bar{0}.0331$	LA-1	0.5165	LE-1	$\bar{0}.6476$
LW-2	0.3632	LH-2	$\bar{0}.4989$	F-2	0.0256	LA-2	1.0000	LE-2	$\bar{0}.6096$
LW-3	0.4368	LH-3	$\bar{0}.2440$	F-3	0.0137	LA-3	0.4505	LE-3	$\bar{0}.5740$
LW-4	0.1691	LH-4	$\bar{0}.3919$	F-4	$\bar{0}.0141$	LA-4	0.9473	LE-4	$\bar{0}.5247$
LW-5	0.2796	LH-5	$\bar{0}.1231$	F-5	$\bar{0}.0436$	LA-5	0.3879	LE-5	$\bar{0}.4379$
LW-6	0.3519	LH-6	$\bar{0}.3022$	F-6	$\bar{0}.0012$	LA-6	0.8945	LE-6	$\bar{0}.3834$
LW-7	0.0357	LH-7	0.1571	F-7	0.0352	LA-7	0.3066	LE-7	$\bar{0}.3124$
LW-8	0.2049	LH-8	$\bar{0}.0330$	F-8	0.0725	LA-8	0.9352	LE-8	$\bar{0}.2745$
LW-9	0.2762	LH-9	$\bar{0}.2300$	F-9	0.0978	LA-9	0.2582	LE-9	$\bar{0}.1890$
LW-10	$\bar{0}.0522$	LH-10	0.1989	F-10	0.0912	LA-10	0.9044	LE-10	$\bar{0}.1729$
LW-11	0.1391	LH-11	$\bar{0}.1754$	Wing Fan		LA-11	0.2297	LE-11	$\bar{0}.1428$
LW-12	0.2095	LH-12	0.2143		Vert. Defl.	LA-12	0.8846	LE-12	$\bar{0}.1448$
LW-13	$\bar{0}.1015$	LH-13	$\bar{0}.1319$	Position	+ Up				
LW-14	0.0834	LH-19	0.0264	LWF-1	$\bar{0}.1945$				
LW-15	0.1532	LH-20	0.0571	LWF-2	$\bar{0}.2604$				
LW-16	$\bar{0}.1226$		F & A Defl.	LWF-3	$\bar{0}.1231$				
LW-17	0.0973		+ Aft	LWF-4	$\bar{0}.1132$				
LW-18	$\bar{0}.1144$			Pitch Fan					
LW-19	0.0527	LH-14	0.0833		Vert. Defl.				
LW-20	$\bar{0}.0909$	LH-15	0.0833	Position	+ Up				
LW-21	0.0255	LH-16	0.0833	NF-1	0.0198				
LW-22	—	LH-17	0.0833						
LW-23	—	LH-18	0.0833						

TABLE 8

SYMMETRIC MODE SHAPE
MODE 5
f = 31.3 cps g = 0.031

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	—	LH-1	0.7397	F-1	0.0174	LA-1	—	LE-1	0.8498
LW-2	—	LH-2	1.0000	F-2	0.0224	LA-2	—	LE-2	0.8653
LW-3	—	LH-3	0.4487	F-3	0.0137	LA-3	—	LE-3	0.7284
LW-4	—	LH-4	0.6784	F-4	$\bar{0}.0037$	LA-4	—	LE-4	0.7375
LW-5	—	LH-5	0.2168	F-5	$\bar{0}.0186$	LA-5	—	LE-5	0.5136
LW-6	—	LH-6	0.4151	F-6	0.0211	LA-6	—	LE-6	0.5144
LW-7	—	LH-7	$\bar{0}.0960$	F-7	0.0336	LA-7	—	LE-7	0.3291
LW-8	—	LH-8	0.0438	F-8	0.0361	LA-8	—	LE-8	0.3267
LW-9	—	LH-9	0.2099	F-9	0.0236	LA-9	—	LE-9	0.1112
LW-10	—	LH-10	$\bar{0}.1550$	F-10	$\bar{0}.0759$	LA-10	—	LE-10	0.1143
LW-11	—	LH-11	0.0629	Wing Fan		LA-11	—	LE-11	0.0037
LW-12	—	LH-12	$\bar{0}.1696$	Position	Vert. Defl. + Up	LA-12	—	LE-12	0.0174
LW-13	—	LH-13	$\bar{0}.0383$						
LW-14	—	LH-19	$\bar{0}.0647$	LWF-1	—				
LW-15	—	LH-20	$\bar{0}.1057$	LWF-2	—				
LW-16	—		F & A Defl. + Aft	LWF-3	—				
LW-17	—			LWF-4	—				
LW-18	—			Pitch Fan					
LW-19	—	LH-14	0.2581	Position	Vert. Defl. + Up				
LW-20	—	LH-15	0.2581						
LW-21	—	LH-16	0.2581	NF-1	—				
LW-22	—	LH-17	0.2581						
LW-23	—	LH-18	0.2581						

TABLE 9

SYMMETRIC MODE SHAPE
MODE 6
f = 36.3 cps g = 0.037

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	$\bar{0}.7443$	LH-1	$\bar{0}.1437$	F-1	0.0562	LA-1	$\bar{0}.7971$	LE-1	$\bar{0}.1514$
LW-2	$\bar{0}.7354$	LH-2	$\bar{0}.1423$	F-2	$\bar{0}.0134$	LA-2	0.7292	LE-2	$\bar{0}.1896$
LW-3	$\bar{0}.7422$	LH-3	$\bar{0}.0967$	F-3	$\bar{0}.0417$	LA-3	$\bar{0}.6286$	LE-3	$\bar{0}.1292$
LW-4	$\bar{0}.5863$	LH-4	$\bar{0}.0906$	F-4	$\bar{0}.0056$	LA-4	0.8333	LE-4	$\bar{0}.1597$
LW-5	$\bar{0}.5986$	LH-5	$\bar{0}.0630$	F-5	0.0952	LA-5	$\bar{0}.4870$	LE-5	$\bar{0}.0833$
LW-6	$\bar{0}.5581$	LH-6	$\bar{0}.0480$	F-6	0.0979	LA-6	0.9201	LE-6	$\bar{0}.1028$
LW-7	$\bar{0}.4448$	LH-7	$\bar{0}.0514$	F-7	0.0299	LA-7	$\bar{0}.3434$	LE-7	$\bar{0}.0424$
LW-8	$\bar{0}.4722$	LH-8	$\bar{0}.0424$	F-8	$\bar{0}.0375$	LA-8	0.9201	LE-8	$\bar{0}.0507$
LW-9	$\bar{0}.3969$	LH-9	$\bar{0}.0146$	F-9	$\bar{0}.0715$	LA-9	$\bar{0}.2850$	LE-9	0.0118
LW-10	$\bar{0}.3196$	LH-10	$\bar{0}.0333$	F-10	$\bar{0}.0368$	LA-10	0.9722	LE-10	0.0153
LW-11	$\bar{0}.3576$	LH-11	0.0096	Wing Fan		LA-11	$\bar{0}.2652$	LE-11	0.0361
LW-12	$\bar{0}.2583$	LH-12	$\bar{0}.0340$	Position	Vert. Defl. + Up	LA-12	1.0000	LE-12	0.0458
LW-13	$\bar{0}.2129$	LH-13	0.0269						
LW-14	$\bar{0}.2569$	LH-19	$\bar{0}.0278$	LWF-1	0.1514				
LW-15	$\bar{0}.1447$	LH-20	$\bar{0}.0201$	LWF-2	0.2000				
LW-16	$\bar{0}.1059$		F & A Defl. + Aft	LWF-3	0.1146				
LW-17	$\bar{0}.0374$			LWF-4	0.2361				
LW-18	$\bar{0}.0222$			Pitch Fan					
LW-19	0.0375	LH-14	$\bar{0}.1345$	Position	Vert. Defl. + Up				
LW-20	0.0360	LH-15	$\bar{0}.1345$						
LW-21	0.0808	LH-16	$\bar{0}.1345$	NF-1	0.0458				
LW-22	—	LH-17	$\bar{0}.1345$						
LW-23	—	LH-18	$\bar{0}.1345$						

TABLE 10

SYMMETRIC MODE SHAPE
MODE 7

f = 44.7 cps g = 0.068

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.1857	LH-1	0.1141	F-1	0.0994	LA-1	$\bar{0}$.2286	LE-1	0.1393
LW-2	0.1335	LH-2	0.1386	F-2	$\bar{0}$.0444	LA-2	1.0000	LE-2	0.1657
LW-3	$\bar{0}$.1001	LH-3	0.0828	F-3	$\bar{0}$.0818	LA-3	$\bar{0}$.2950	LE-3	0.1250
LW-4	0.3233	LH-4	0.1082	F-4	$\bar{0}$.0534	LA-4	0.9429	LE-4	0.1514
LW-5	0.2046	LH-5	0.0558	F-5	$\bar{0}$.0168	LA-5	$\bar{0}$.3486	LE-5	0.0978
LW-6	$\bar{0}$.1944	LH-6	0.0820	F-6	$\bar{0}$.0114	LA-6	0.8893	LE-6	0.1243
LW-7	0.3949	LH-7	0.0309	F-7	$\bar{0}$.0071	LA-7	$\bar{0}$.4129	LE-7	0.0736
LW-8	0.2381	LH-8	0.0331	F-8	0.0314	LA-8	0.8679	LE-8	0.1000
LW-9	$\bar{0}$.2519	LH-9	0.0599	F-9	0.0686	LA-9	$\bar{0}$.4450	LE-9	0.0440
LW-10	0.4121	LH-10	$\bar{0}$.0102	F-10	0.0414	LA-10	0.8214	LE-10	0.0714
LW-11	0.2344	LH-11	0.0386	Wing Fan		LA-11	$\bar{0}$.4500	LE-11	0.0315
LW-12	$\bar{0}$.2809	LH-12	$\bar{0}$.0354	Position	Vert. Defl. + Up	LA-12	0.8021	LE-12	0.0604
LW-13	0.3874	LH-13	0.0286						
LW-14	0.1944	LH-19	0.0143	LWF-1	0.0821				
LW-15	$\bar{0}$.2846	LH-20	0.0043	LWF-2	$\bar{0}$.0964				
LW-16	0.3192		F & A Defl. + Aft	LWF-3	$\bar{0}$.1464				
LW-17	$\bar{0}$.2611			LWF-4	$\bar{0}$.0643				
LW-18	0.2293			Pitch Fan					
LW-19	$\bar{0}$.2143	LH-14	0.0637	Position	Vert. Defl. + Up				
LW-20	0.1366	LH-15	0.0637						
LW-21	$\bar{0}$.1496	LH-16	0.0637	NF-1	0.0586				
LW-22	—	LH-17	0.0637						
LW-23	—	LH-18	0.0637						

TABLE 11

SYMMETRIC MODE SHAPE
MODE 8
f = 55.9 cps g = 0.033

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	$\bar{0}.2775$	LH-1	0.5141	F-1	0.0168	LA-1	$\bar{0}.3033$	LE-1	0.2684
LW-2	$\bar{0}.2562$	LH-2	0.2916	F-2	$\bar{0}.0110$	LA-2	$\bar{0}.5990$	LE-2	0.3123
LW-3	$\bar{0}.2360$	LH-3	0.3335	F-3	$\bar{0}.0200$	LA-3	$\bar{0}.2904$	LE-3	0.1036
LW-4	$\bar{0}.2479$	LH-4	0.0458	F-4	$\bar{0}.0226$	LA-4	$\bar{0}.7528$	LE-4	0.1058
LW-5	$\bar{0}.2284$	LH-5	0.1878	F-5	$\bar{0}.0045$	LA-5	$\bar{0}.2646$	LE-5	$\bar{0}.1536$
LW-6	$\bar{0}.2069$	LH-6	$\bar{0}.1393$	F-6	0.0019	LA-6	$\bar{0}.4754$	LE-6	$\bar{0}.2112$
LW-7	$\bar{0}.2181$	LH-7	0.2542	F-7	$\bar{0}.0161$	LA-7	$\bar{0}.2420$	LE-7	$\bar{0}.3243$
LW-8	$\bar{0}.2000$	LH-8	0.0770	F-8	$\bar{0}.0277$	LA-8	0.2934	LE-8	$\bar{0}.4136$
LW-9	$\bar{0}.1786$	LH-9	$\bar{0}.2635$	F-9	$\bar{0}.0290$	LA-9	$\bar{0}.2194$	LE-9	$\bar{0}.4388$
LW-10	$\bar{0}.1882$	LH-10	0.1652	F-10	$\bar{0}.0064$	LA-10	0.7983	LE-10	$\bar{0}.4982$
LW-11	$\bar{0}.1710$	LH-11	$\bar{0}.3149$	Wing Fan		LA-11	$\bar{0}.2065$	LE-11	$\bar{0}.3775$
LW-12	$\bar{0}.1511$	LH-12	0.1361	Position	Vert. Defl. + Up	LA-12	1.0000	LE-12	$\bar{0}.4252$
LW-13	$\bar{0}.1589$	LH-13	$\bar{0}.3259$						
LW-14	$\bar{0}.1420$	LH-19	0.0277	LWF-1	$\bar{0}.0458$				
LW-15	$\bar{0}.1249$	LH-20	0.0006	LWF-2	$\bar{0}.0536$				
LW-16	$\bar{0}.1238$		F & A Defl. + Aft	LWF-3	$\bar{0}.0419$				
LW-17	$\bar{0}.0947$			LWF-4	$\bar{0}.0426$				
LW-18	$\bar{0}.0892$			Pitch Fan					
LW-19	$\bar{0}.0658$	LH-14	$\bar{0}.0439$	Position	Vert. Defl. + Up				
LW-20	$\bar{0}.0566$	LH-15	$\bar{0}.0439$						
LW-21	$\bar{0}.0399$	LH-16	$\bar{0}.0439$	NF-1	0.0103				
LW-22	—	LH-17	$\bar{0}.0439$						
LW-23	—	LH-18	$\bar{0}.0439$						

TABLE 12

SYMMETRIC MODE SHAPE
MODE 9
$f = 67.8$ cps $g = 0.031$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.5975	LH-1	$\bar{0}.0207$	F-1	0.1230	LA-1	0.8363	LE-1	$\bar{0}.0186$
LW-2	0.6500	LH-2	$\bar{0}.0142$	F-2	$\bar{0}.1013$	LA-2	1.0000	LE-2	0.0308
LW-3	0.6925	LH-3	$\bar{0}.0176$	F-3	$\bar{0}.0934$	LA-3	0.5034	LE-3	$\bar{0}.0175$
LW-4	0.1122	LH-4	$\bar{0}.0138$	F-4	0.0184	LA-4	0.6842	LE-4	0.0300
LW-5	0.1697	LH-5	$\bar{0}.0153$	F-5	0.0371	LA-5	0.2078	LE-5	$\bar{0}.0153$
LW-6	0.2172	LH-6	$\bar{0}.0134$	F-6	0.0196	LA-6	0.4079	LE-6	0.0286
LW-7	$\bar{0}.1921$	LH-7	$\bar{0}.0234$	F-7	0.0103	LA-7	$\bar{0}.1268$	LE-7	$\bar{0}.0132$
LW-8	$\bar{0}.1474$	LH-8	$\bar{0}.0133$	F-8	0.0011	LA-8	$\bar{0}.2303$	LE-8	0.0271
LW-9	$\bar{0}.0895$	LH-9	$\bar{0}.0132$	F-9	$\bar{0}.0071$	LA-9	$\bar{0}.2976$	LE-9	$\bar{0}.0100$
LW-10	$\bar{0}.3479$	LH-10	$\bar{0}.0172$	F-10	$\bar{0}.0203$	LA-10	$\bar{0}.3947$	LE-10	0.0249
LW-11	$\bar{0}.3079$	LH-11	$\bar{0}.0128$	Wing Fan		LA-11	$\bar{0}.3837$	LE-11	$\bar{0}.0080$
LW-12	$\bar{0}.2568$	LH-12	$\bar{0}.0150$	Position	Vert. Defl. + Up	LA-12	$\bar{0}.4947$	LE-12	0.0234
LW-13	$\bar{0}.3875$	LH-13	$\bar{0}.0124$						
LW-14	$\bar{0}.3553$	LH-19	$\bar{0}.0125$	LWF-1	0.1579				
LW-15	$\bar{0}.3137$	LH-20	$\bar{0}.0125$	LWF-2	0.2237				
LW-16	$\bar{0}.3308$		F & A Defl. + Aft	LWF-3	0.1237				
LW-17	$\bar{0}.2814$			LWF-4	0.1303				
LW-18	$\bar{0}.2079$	LH-14	—	Pitch Fan					
LW-19	$\bar{0}.1842$	LH-15	—	Position	Vert. Defl. + Up				
LW-20	$\bar{0}.0867$	LH-16	—	NF-1	0.0882				
LW-21	$\bar{0}.0782$	LH-17	—						
LW-22	—	LH-18	—						
LW-23	—		—						

TABLE 13

SYMMETRIC MODE SHAPE
MODE 10
f = 90.3 cps g = 0.031

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	—	LH-1	$\bar{0}.5083$	F-1	—	LA-1	—	LE-1	0.7170
LW-2	—	LH-2	0.6187	F-2	—	LA-2	—	LE-2	1.0000
LW-3	—	LH-3	$\bar{0}.3619$	F-3	—	LA-3	—	LE-3	0.8679
LW-4	—	LH-4	0.2383	F-4	—	LA-4	—	LE-4	0.9811
LW-5	—	LH-5	$\bar{0}.2419$	F-5	0.0009	LA-5	—	LE-5	0.6226
LW-6	—	LH-6	$\bar{0}.0475$	F-6	0.0206	LA-6	—	LE-6	0.7170
LW-7	—	LH-7	$\bar{0}.1630$	F-7	0.0725	LA-7	—	LE-7	$\bar{0}.0943$
LW-8	—	LH-8	$\bar{0}.1483$	F-8	$\bar{0}.0389$	LA-8	—	LE-8	0.2736
LW-9	—	LH-9	$\bar{0}.2394$	F-9	$\bar{0}.1985$	LA-9	—	LE-9	$\bar{0}.5660$
LW-10	—	LH-10	0.0951	F-10	0.1225	LA-10	—	LE-10	$\bar{0}.5660$
LW-11	—	LH-11	$\bar{0}.3370$	Wing Fan		LA-11	—	LE-11	$\bar{0}.4717$
LW-12	—	LH-12	0.2366	Position	Vert. Defl. + Up	LA-12	—	LE-12	$\bar{0}.4717$
LW-13	—	LH-13	$\bar{0}.3396$						
LW-14	—	LH-19	0.0660	LWF-1	—				
LW-15	—	LH-20	$\bar{0}.0189$	LWF-2	—				
LW-16	—		F & A Defl. + Aft	LWF-3	—				
LW-17	—			LWF-4	—				
LW-18	—	LH-14	0.1142	Pitch Fan					
LW-19	—	LH-15	0.1142	Position	Vert. Defl. + Up				
LW-20	—	LH-16	0.1142						
LW-21	—	LH-17	0.1142	NF-1	—				
LW-22	—	LH-18	0.1142						
LW-23	—								

TABLE 14

ANTISYMMETRIC MODE SHAPE
MODE 1
f = 8.8 cps g = 0.030

Wing Position	Wing Vert. Defl. + Up
LW-1	$\bar{0}$.2549
LW-2	$\bar{0}$.2665
LW-3	$\bar{0}$.2588
LW-4	$\bar{0}$.2140
LW-5	$\bar{0}$.2245
LW-6	$\bar{0}$.2241
LW-7	$\bar{0}$.1790
LW-8	$\bar{0}$.1907
LW-9	$\bar{0}$.1899
LW-10	$\bar{0}$.1498
LW-11	$\bar{0}$.1623
LW-12	$\bar{0}$.1556
LW-13	$\bar{0}$.1214
LW-14	$\bar{0}$.1374
LW-15	$\bar{0}$.1237
LW-16	$\bar{0}$.0918
LW-17	$\bar{0}$.0895
LW-18	$\bar{0}$.0626
LW-19	$\bar{0}$.0595
LW-20	$\bar{0}$.0401
LW-21	$\bar{0}$.0381
LW-22	–
LW-23	–
	F & A Defl. + Aft
LW-24	$\bar{0}$.2288
LW-25	$\bar{0}$.1821
LW-26	$\bar{0}$.1362
LW-27	$\bar{0}$.0825

Horiz. Stab. Position	Horiz. Stab. Vert. Defl. + Up
LH-1	0.9689
LH-2	1.0000
LH-3	0.7782
LH-4	0.8171
LH-5	0.5992
LH-6	0.6304
LH-7	0.4280
LH-8	0.4163
LH-9	0.4358
LH-10	0.2335
LH-11	0.2412
LH-19	0.2335
	Lat. Defl. + Left
LH-12	$\bar{0}$.8482
LH-13	$\bar{0}$.9728
LH-20	$\bar{0}$.8755
	F & A Defl. + Aft
LH-14	0.2054
LH-15	0.3716
LH-16	0.5377
LH-17	0.7039
LH-18	0.8700

Vert. Stab. Position	Vert. Stab. Lat. Defl. + Left
V-1	$\bar{0}$.0525
V-2	$\bar{0}$.0895
V-3	$\bar{0}$.0946
V-4	$\bar{0}$.1304
V-5	$\bar{0}$.1907
V-6	$\bar{0}$.2218
V-7	$\bar{0}$.2996
V-8	$\bar{0}$.3307
V-9	$\bar{0}$.4144
V-10	$\bar{0}$.4552
V-11	$\bar{0}$.5447
V-12	$\bar{0}$.6420
V-13	$\bar{0}$.7043
V-14	$\bar{0}$.1704
V-15	$\bar{0}$.2685
V-16	$\bar{0}$.3813
V-17	$\bar{0}$.5097
F-25	0.0778
F-26	0.0595
F-27	0.0245

Fuselage (WL 100) Position	Lat. Defl. + Left	Ang. Defl. X10³*
F-11-12	$\bar{0}$.2062	0.3891
F-13-14	$\bar{0}$.1370	0.3891
F-15-16	$\bar{0}$.0428	0.3891
F-17-18	0.0000	0.3891
F-19-20	0.0673	$\bar{0}$.1249
F-21-22	0.0860	$\bar{0}$.6257
F-23-24	0.0860	$\bar{1}$.0245
F-25-30	0.0778	$\bar{1}$.8482
F-26-31	0.0603	$\bar{2}$.6264
F-27-32	0.0268	$\bar{3}$.4630

Wing Fan Position	Vert. Defl. + Up
LWF-1	$\bar{0}$.4280
LWF-2	$\bar{0}$.6926
LWF-3	$\bar{0}$.2685
LWF-4	$\bar{0}$.2724

Aileron Position	Aileron Vert. Defl. + Up	Elevator Position	Elevator Vert. Defl. + Up	Rudder Position	Rudder Lat. Defl. + Left
LA-1	$\bar{0}$.3268	LE-1	0.9844	R-1	$\bar{0}$.6089
LA-2	$\bar{0}$.3502	LE-2	0.9844	R-2	$\bar{0}$.6089
LA-3	$\bar{0}$.3016	LE-3	0.8949	R-3	$\bar{0}$.4786
LA-4	$\bar{0}$.3230	LE-4	0.8949	R-4	$\bar{0}$.4786
LA-5	$\bar{0}$.2743	LE-5	0.7198	R-5	$\bar{0}$.3696
LA-6	$\bar{0}$.2957	LE-6	0.7198	R-6	$\bar{0}$.3696
LA-7	$\bar{0}$.2374	LE-7	0.5331	R-7	$\bar{0}$.3619
LA-8	$\bar{0}$.2588	LE-8	0.5331	R-8	$\bar{0}$.3152
LA-9	$\bar{0}$.2101	LE-9	0.2529	R-9	$\bar{0}$.2646
LA-10	$\bar{0}$.2335	LE-10	0.2529	R-10	$\bar{0}$.2257
LA-11	$\bar{0}$.1907	LE-11	0.0778	R-11	$\bar{0}$.1732
LA-12	$\bar{0}$.2179	LE-12	0.0778	R-12	$\bar{0}$.1401

* Left Wing Down

TABLE 15

ANTISYMMETRIC MODE SHAPE
MODE 2
f = 11.9 cps g = 0.045

Wing

Position	Vert. Defl. + Up
LW-1	0.0465
LW-2	0.0451
LW-3	0.0478
LW-4	0.0382
LW-5	0.0373
LW-6	0.0382
LW-7	0.0300
LW-8	0.0300
LW-9	0.0306
LW-10	0.0229
LW-11	0.0239
LW-12	0.0239
LW-13	0.0184
LW-14	0.0199
LW-15	0.0191
LW-16	0.0109
LW-17	0.0134
LW-18	0.0057
LW-19	0.0086
LW-20	0.0029
LW-21	0.0048
LW-22	—
LW-23	—

Position	F & A Defl. + Aft
LW-24	0.0404
LW-25	0.0321
LW-26	0.0241
LW-27	0.0145

Horiz. Stab.

Position	Vert. Defl. + Up
LH-1	$\bar{0}.5833$
LH-2	$\bar{0}.5833$
LH-3	$\bar{0}.4720$
LH-4	$\bar{0}.4720$
LH-5	$\bar{0}.3605$
LH-6	$\bar{0}.3605$
LH-7	$\bar{0}.2492$
LH-8	$\bar{0}.2492$
LH-9	$\bar{0}.2492$
LH-10	$\bar{0}.1377$
LH-11	$\bar{0}.1377$
LH-19	$\bar{0}.1377$

Position	Lat. Defl. + Left
LH-12	0.5068
LH-13	0.0765
LH-20	0.3155

Position	F & A Defl. + Aft
LH-14	0.2360
LH-15	0.4270
LH-16	0.6181
LH-17	0.8091
LH-18	1.0000

Vert. Stab.

Position	Lat. Defl. + Left
V-1	0.0239
V-2	$\bar{0}.0038$
V-3	$\bar{0}.0249$
V-4	0.0430
V-5	$\bar{0}.0105$
V-6	0.0669
V-7	0.0086
V-8	0.0918
V-9	0.0277
V-10	0.1243
V-11	0.0516
V-12	0.0708
V-13	0.1071
V-14	0.0115
V-15	0.0287
V-16	0.0459
V-17	0.0688
F-25	$\bar{0}.0235$
F-26	$\bar{0}.0352$
F-27	$\bar{0}.0493$

Fuselage (WL 100)

Position	Lat. Defl. + Left	Ang. Defl. $X10^3$*
F-11-12	$\bar{0}.0321$	$\bar{0}.0482$
F-13-14	$\bar{0}.0208$	$\bar{0}.0350$
F-15-16	$\bar{0}.0054$	$\bar{0}.0073$
F-17-18	0.0023	$\bar{0}.0371$
F-19-20	0.0084	$\bar{0}.0302$
F-21-22	$\bar{0}.0046$	$\bar{0}.0316$
F-23-24	$\bar{0}.0080$	0.0074
F-25-30	$\bar{0}.0235$	0.1100
F-26-31	$\bar{0}.0352$	0.1893
F-27-32	$\bar{0}.0495$	0.3060

Wing Fan

Position	Vert. Defl. + Up
LWF-1	0.0880
LWF-2	0.1186
LWF-3	0.0382
LWF-4	0.0421

Aileron

Position	Vert. Defl. + Up
LA-1	0.0478
LA-2	0.0602
LA-3	0.0411
LA-4	0.0545
LA-5	0.0354
LA-6	0.0478
LA-7	0.0289
LA-8	0.0325
LA-9	0.0229
LA-10	0.0287
LA-11	0.0218
LA-12	0.0249

Elavator

Position	Vert. Defl. + Up
LE-1	$\bar{0}.5355$
LE-2	$\bar{0}.4877$
LE-3	$\bar{0}.4838$
LE-4	$\bar{0}.4399$
LE-5	$\bar{0}.3787$
LE-6	$\bar{0}.3481$
LE-7	$\bar{0}.2754$
LE-8	$\bar{0}.2544$
LE-9	$\bar{0}.1300$
LE-10	$\bar{0}.1147$
LE-11	$\bar{0}.0344$
LE-12	$\bar{0}.0268$

Rudder

Position	Lat. Defl. + Left
R-1	0.0363
R-2	0.0478
R-3	0.0048
R-4	$\bar{0}.0191$
R-5	$\bar{0}.0191$
R-6	$\bar{0}.0000$
R-7	$\bar{0}.0287$
R-8	$\bar{0}.0105$
R-9	$\bar{0}.0478$
R-10	$\bar{0}.0268$
R-11	$\bar{0}.0612$
R-12	$\bar{0}.0402$

* Left Wing Down

TABLE 16

ANTISYMMETRIC MODE SHAPE
MODE 3
f = 14.5 cps g = 0.023

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10³*	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	$\bar{0}.0450$	LH-1	1.0000	V-1	0.3413	F-11-12	0.2026	0.4158	LA-1	$\bar{0}.0413$	LE-1	0.9587	F-1	0.3357
LW-2	$\bar{0}.0390$	LH-2	0.8948	V-2	0.3788	F-13-14	0.1290	0.4524	LA-2	$\bar{0}.0413$	LE-2	0.9782	F-2	0.3151
LW-3	$\bar{0}.0405$	LH-3	0.8091	V-3	0.4492	F-15-16	0.0210	0.1662	LA-3	$\bar{0}.0353$	LE-3	0.8667	F-3	0.4032
LW-4	$\bar{0}.0413$	LH-4	0.7239	V-4	0.3563	F-17-18	$\bar{0}.0270$	$\bar{0}.0803$	LA-4	$\bar{0}.0353$	LE-4	0.8843	F-4	0.3751
LW-5	$\bar{0}.0323$	LH-5	0.6180	V-5	0.4351	F-19-20	$\bar{0}.0315$	0.8730	LA-5	$\bar{0}.0304$	LE-5	0.6868	F-5	0.4482
LW-6	$\bar{0}.0338$	LH-6	0.5529	V-6	0.3638	F-21-22	0.0375	0.8740	LA-6	$\bar{0}.0304$	LE-6	0.7009	F-6	0.4107
LW-7	$\bar{0}.0381$	LH-7	0.3563	V-7	0.4164	F-23-24	0.1440	0.4242	LA-7	$\bar{0}.0246$	LE-7	0.5071	F-7	0.4623
LW-8	$\bar{0}.0268$	LH-8	0.4270	V-8	0.3601	F-25-30	0.2626	$\bar{0}.2251$	LA-8	$\bar{0}.0246$	LE-8	0.5173	F-8	0.4276
LW-9	$\bar{0}.0285$	LH-9	0.3820	V-9	0.3798	F-26-31	0.3526	$\bar{0}.7502$	LA-9	$\bar{0}.0208$	LE-9	0.2410	F-9	0.4745
LW-10	$\bar{0}.0341$	LH-10	0.1969	V-10	0.3441	F-27-32	0.4411	$\bar{1}.4398$	LA-10	$\bar{0}.0208$	LE-10	0.2461	F-10	0.4464
LW-11	$\bar{0}.0231$	LH-11	0.2112	V-11	0.3320		Wing Fan		LA-11	$\bar{0}.0189$	LE-11	0.0671	F-11	0.4839
LW-12	$\bar{0}.0231$	LH-19	0.2361	V-12	0.2907				LA-12	$\bar{0}.0189$	LE-12	0.0686	F-12	0.4632
LW-13	$\bar{0}.0300$		Lat. Defl. + Left	V-13	0.2701		Position	Vert. Defl. + Up						
LW-14	$\bar{0}.0191$			V-14	0.3807		LWF-1	$\bar{0}.1838$						
LW-15	$\bar{0}.0191$			V-15	0.3788		LWF-2	$\bar{0}.2251$						
LW-16	$\bar{0}.0259$	LH-12	0.2626	V-16	0.3620		LWF-3	$\bar{0}.1125$						
LW-17	$\bar{0}.0150$	LH-13	0.1875	V-17	0.3310		LWF-4	$\bar{0}.1107$						
LW-18	$\bar{0}.0206$	LH-20	0.2251	F-25	0.2626									
LW-19	$\bar{0}.0109$		F & A Defl. + Aft	F-26	0.3524									
LW-20	$\bar{0}.0150$			F-27	0.4432									
LW-21	$\bar{0}.0071$	LH-14	0.1510											
LW-22	—	LH-15	0.2733											
LW-23	—	LH-16	0.3955											
	F & A Defl. + Aft	LH-17	0.5178											
		LH-18	0.6399											
LW-24	0.1002													
LW-25	0.0797													
LW-26	0.0596													
LW-27	0.0356													

* Left Wing Down

TABLE 17

ANTISYMMETRIC MODE SHAPE
MODE 4
f = 18. 5 cps g = 0.046

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10^3*	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	0.6114	LH-1	0.4456	V-1	0.0145	F-11-12	$\bar{0}$.1518	4.6197	LA-1	0.7130	LE-1	0.4508	R-1	0.0249
LW-2	0.6114	LH-2	0.4829	V-2	$\bar{0}$.0124	F-13-14	$\bar{0}$.1024	3.6062	LA-2	1.0000	LE-2	0.4684	R-2	0.0383
LW-3	0.6777	LH-3	0.3378	V-3	$\bar{0}$.0477	F-15-16	$\bar{0}$.0398	3.6497	LA-3	0.6176	LE-3	0.4000	R-3	$\bar{0}$.0062
LW-4	0.4269	LH-4	0.3689	V-4	0.0352	F-17-18	$\bar{0}$.0247	3.9026	LA-4	0.9119	LE-4	0.4166	R-4	0.0135
LW-5	0.4684	LH-5	0.2404	V-5	$\bar{0}$.0187	F-19-20	$\bar{0}$.0332	3.2974	LA-5	0.5285	LE-5	0.3067	R-5	$\bar{0}$.0332
LW-6	0.5513	LH-6	0.2632	V-6	0.0497	F-21-22	$\bar{0}$.0452	3.0508	LA-6	0.8290	LE-6	0.3171	R-6	$\bar{0}$.0104
LW-7	0.2653	LH-7	0.1492	V-7	0.0083	F-23-24	$\bar{0}$.0622	2.8062	LA-7	0.4104	LE-7	0.2176	R-7	$\bar{0}$.0394
LW-8	0.3420	LH-8	0.1513	V-8	0.0580	F-25-30	$\bar{0}$.0794	2.6943	LA-8	0.6591	LE-8	0.2228	R-8	$\bar{0}$.0218
LW-9	0.4332	LH-9	0.1679	V-9	0.0280	F-26-31	$\bar{0}$.0920	2.7606	LA-9	0.3347	LE-9	0.0933	R-9	$\bar{0}$.0591
LW-10	0.1306	LH-10	0.0808	V-10	0.0642	F-27-32	$\bar{0}$.1096	3.0466	LA-10	0.5907	LE-10	0.0995	R-10	$\bar{0}$.0435
LW-11	0.2342	LH-11	0.0767	V-11	0.0404		Wing Fan		LA-11	0.2839	LE-11	0.0228	R-11	$\bar{0}$.0788
LW-12	0.3275	LH-19	0.0767	V-12	0.0415			Vert. Defl	LA-12	0.5492	LE-12	0.0311	R-12	$\bar{0}$.0642
LW-13	0.0311		Lat. Defl.	V-13	0.0508		Position	+ Up						
LW-14	0.1575		+ Up	V-14	0.0124		LWF-1	$\bar{0}$.2073						
LW-15	0.2332	LH-12	0.0199	V-15	0.0301		LWF-2	$\bar{0}$.2902						
LW-16	$\bar{0}$.0539	LH-13	0.0143	V-16	0.0425		LWF-3	$\bar{0}$.1762						
LW-17	0.1347	LH-20	0.0174	V-17	0.0518		LWF-4	$\bar{0}$.1492						
LW-18	$\bar{0}$.0953			F-25	$\bar{0}$.0794									
LW-19	0.0518		F & A Defl.	F-26	$\bar{0}$.0914									
LW-20	$\bar{0}$.0933		+ Aft	F-27	$\bar{0}$.1076									
LW-21	$\bar{0}$.0207	LH-14	0.0166											
LW-22	—	LH-15	0.0290											
LW-23	—	LH-16	0.0435											
	F & A Defl.	LH-17	0.0570											
	+ Aft	LH-18	0.0705											
LW-24	0.0151													
LW-25	0.0095													
LW-26	0.0064													
LW-27	0.0048													

* Left Wing Down

TABLE 18

ANTISYMMETRIC MODE SHAPE
MODE 5
f = 23.0 cps g = 0.019

Wing

Position	Vert. Defl. + Up
LW-1	0.4138
LW-2	0.4828
LW-3	0.5222
LW-4	0.2833
LW-5	0.3768
LW-6	0.4557
LW-7	0.1601
LW-8	0.2808
LW-9	0.3926
LW-10	0.0394
LW-11	0.1897
LW-12	0.3300
LW-13	$\bar{0}.0640$
LW-14	0.1084
LW-15	0.2685
LW-16	$\bar{0}.1256$
LW-17	0.2044
LW-18	$\bar{0}.1232$
LW-19	0.1429
LW-20	$\bar{0}.0936$
LW-21	0.0887
LW-22	—
LW-23	—
	F & A Defl. + Aft
LW-24	$\bar{0}.2739$
LW-25	$\bar{0}.2182$
LW-26	$\bar{0}.1635$
LW-27	$\bar{0}.0990$

Horiz. Stab.

Position	Vert. Defl. + Up
LH-1	$\bar{0}.6034$
LH-2	$\bar{0}.7167$
LH-3	$\bar{0}.4557$
LH-4	$\bar{0}.5320$
LH-5	$\bar{0}.3261$
LH-6	$\bar{0}.3695$
LH-7	$\bar{0}.1823$
LH-8	$\bar{0}.2084$
LH-9	$\bar{0}.2315$
LH-10	$\bar{0}.0813$
LH-11	$\bar{0}.1123$
LH-19	$\bar{0}.1034$
	Lat. Defl. + Left
LH-12	$\bar{0}.4286$
LH-13	$\bar{0}.2759$
LH-20	$\bar{0}.3448$
	F & A Defl. + Aft
LH-14	$\bar{0}.0690$
LH-15	$\bar{0}.1246$
LH-16	$\bar{0}.1803$
LH-17	$\bar{0}.2360$
LH-18	$\bar{0}.2916$

Vert. Stab.

Position	Lat. Defl. + Left
V-1	0.0665
V-2	0.0788
V-3	0.1576
V-4	0.0123
V-5	0.0788
V-6	$\bar{0}.0493$
V-7	$\bar{0}.0049$
V-8	$\bar{0}.1232$
V-9	$\bar{0}.0985$
V-10	$\bar{0}.1970$
V-11	$\bar{0}.2069$
V-12	$\bar{0}.3005$
V-13	$\bar{0}.3547$
V-14	0.0123
V-15	$\bar{0}.0542$
V-16	$\bar{0}.1305$
V-17	$\bar{0}.2118$
F-25	0.2222
F-26	0.2601
F-27	0.2640

Fuselage (WL 100)

Position	Lat. Defl. + Left	Ang. Defl. X10^3 *
F-11-12	0.2241	3.0764
F-13-14	0.0665	6.2483
F-15-16	$\bar{0}.0596$	3.9847
F-17-18	$\bar{0}.0877$	3.3768
F-19-20	$\bar{0}.0483$	2.6424
F-21-22	0.0296	1.7734
F-23-24	0.1300	0.2138
F-25-30	0.2222	$\bar{1}.7631$
F-26-31	0.2611	$\bar{3}.1527$
F-27-32	0.2675	$\bar{4}.5872$

Wing Fan

Position	Vert. Defl. + Up
LWF-1	$\bar{0}.1527$
LWF-2	$\bar{0}.2512$
LWF-3	0.0576
LWF-4	$\bar{0}.0552$

Aileron

Position	Vert. Defl. + Up
LA-1	0.6256
LA-2	1.0000
LA-3	0.5788
LA-4	0.9542
LA-5	0.5320
LA-6	0.9089
LA-7	0.4695
LA-8	0.7709
LA-9	0.4286
LA-10	0.7325
LA-11	0.4015
LA-12	0.7079

Elevator

Position	Vert. Defl. + Up
LE-1	$\bar{0}.7241$
LE-2	$\bar{0}.6700$
LE-3	$\bar{0}.6305$
LE-4	$\bar{0}.5764$
LE-5	$\bar{0}.4631$
LE-6	$\bar{0}.4039$
LE-7	$\bar{0}.3153$
LE-8	$\bar{0}.2364$
LE-9	$\bar{0}.1330$
LE-10	$\bar{0}.0172$
LE-11	$\bar{0}.0345$
LE-12	0.1084

Rudder

Position	Lat. Defl. + Left
R-1	$\bar{0}.2414$
R-2	$\bar{0}.2414$
R-3	$\bar{0}.1182$
R-4	$\bar{0}.1182$
R-5	$\bar{0}.0197$
R-6	$\bar{0}.0197$
R-7	0.0246
R-8	0.0246
R-9	0.0985
R-10	0.0985
R-11	0.1675
R-12	0.1675

* Left Wing Down

TABLE 19

ANTISYMMETRIC MODE SHAPE

MODE 6

f = 25.3 cps g = 0.046

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10³*	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	0.3823	LH-1	0.4248	V-1	$\bar{0}$.0619	F-11-12	$\bar{0}$.0685	$\bar{6}$.9942	LA-1	0.5591	LE-1	0.5310	R-1	0.1540
LW-2	0.4313	LH-2	0.4903	V-2	$\bar{0}$.0602	F-13-14	$\bar{0}$.0159	$\bar{3}$.4280	LA-2	1.0000	LE-2	0.5133	R-2	0.1027
LW-3	0.4704	LH-3	0.3133	V-3	$\bar{0}$.0841	F-15-16	0.0301	$\bar{2}$.2271	LA-3	0.4956	LE-3	0.4513	R-3	0.0735
LW-4	0.2628	LH-4	0.3575	V-4	$\bar{0}$.0363	F-17-18	0.0441	$\bar{2}$.0018	LA-4	0.9575	LE-4	0.4336	R-4	0.0310
LW-5	0.3274	LH-5	0.2088	V-5	$\bar{0}$.0478	F-19-20	0.0354	$\bar{1}$.7342	LA-5	0.4398	LE-5	0.3186	R-5	0.0071
LW-6	0.3850	LH-6	0.2425	V-6	$\bar{0}$.0071	F-21-22	0.0000	$\bar{1}$.2389	LA-6	0.9230	LE-6	0.3080	R-6	$\bar{0}$.0230
LW-7	0.1717	LH-7	0.1026	V-7	$\bar{0}$.0088	F-23-24	$\bar{0}$.0579	$\bar{0}$.4779	LA-7	0.3761	LE-7	0.2195	R-7	$\bar{0}$.0230
LW-8	0.2411	LH-8	0.1124	V-8	0.0319	F-25-30	$\bar{0}$.1177	0.3540	LA-8	0.7292	LE-8	0.2088	R-8	$\bar{0}$.0487
LW-9	0.3150	LH-9	0.1389	V-9	0.0327	F-26-31	$\bar{0}$.1416	1.0619	LA-9	0.3363	LE-9	0.0973	R-9	$\bar{0}$.0761
LW-10	0.1027	LH-10	0.0336	V-10	0.0796	F-27-32	$\bar{0}$.1480	1.9802	LA-10	0.7027	LE-10	0.0938	R-10	$\bar{0}$.0920
LW-11	0.1681	LH-11	0.0584	V-11	0.0814		Wing Fan		LA-11	0.3097	LE-11	0.0310	R-11	$\bar{0}$.1257
LW-12	0.2566	LH-19	0.0354	V-12	0.1212		Position	Vert. Defl. + Up	LA-12	0.6876	LE-12	0.0265	R-12	$\bar{0}$.1310
LW-13	0.0487		Lat. Defl. + Left	V-13	0.1558		LWF-1	$\bar{0}$.2124						
LW-14	0.0970	LH-12	0.1770	V-14	$\bar{0}$.0319		LWF-2	$\bar{0}$.3115						
LW-15	0.2018	LH-13	0.1274	V-15	0.0000		LWF-3	$\bar{0}$.0814						
LW-16	$\bar{0}$.0106	LH-20	0.1522	V-16	0.0354		LWF-4	$\bar{0}$.1257						
LW-17	0.1416		F & A Defl. + Aft	V-17	0.0814									
LW-18	$\bar{0}$.0593	LH-14	0.0381	F-25	$\bar{0}$.1177									
LW-19	0.0850	LH-15	0.0690	F-26	$\bar{0}$.1414									
LW-20	$\bar{0}$.0726	LH-16	0.0998	F-27	$\bar{0}$.1465									
LW-21	0.0487	LH-17	0.1306											
LW-22	—	LH-18	0.1614											
LW-23	—													
	F & A Defl. + Aft													
LW-24	$\bar{0}$.0857													
LW-25	$\bar{0}$.0683													
LW-26	$\bar{0}$.0512													
LW-27	$\bar{0}$.0310													

* Left Wing Down

TABLE 20

ANTISYMMETRIC MODE SHAPE
MODE 7
f = 34.8 cps g = 0.040

Wing

Position	Vert. Defl. + Up
LW-1	$\bar{0}$.6408
LW-2	$\bar{0}$.5915
LW-3	$\bar{0}$.5676
LW-4	$\bar{0}$.5535
LW-5	$\bar{0}$.4563
LW-6	$\bar{0}$.3268
LW-7	$\bar{0}$.4746
LW-8	$\bar{0}$.3380
LW-9	$\bar{0}$.1296
LW-10	$\bar{0}$.4028
LW-11	$\bar{0}$.2324
LW-12	0.0239
LW-13	$\bar{0}$.3296
LW-14	$\bar{0}$.1577
LW-15	0.1268
LW-16	$\bar{0}$.2479
LW-17	0.1958
LW-18	$\bar{0}$.1746
LW-19	0.2056
LW-20	$\bar{0}$.1127
LW-21	0.1620
LW-22	—
LW-23	—
	F & A Defl. + Aft
LW-24	$\bar{0}$.0944
LW-25	$\bar{0}$.0752
LW-26	$\bar{0}$.0562
LW-27	$\bar{0}$.0341

Horiz. Stab.

Position	Vert. Defl. + Up
LH-1	0.0563
LH-2	0.0423
LH-3	0.0338
LH-4	0.0225
LH-5	0.0183
LH-6	0.0127
LH-7	0.0423
LH-8	0.0113
LH-9	0.0056
LH-10	0.0225
LH-11	0.0028
LH-19	0.0056
	Lat. Defl. + Left
LH-12	0.0479
LH-13	0.0310
LH-20	0.0408
	F & A Defl. + Aft
LH-14	0.0063
LH-15	0.0114
LH-16	0.0165
LH-17	0.0217
LH-18	0.0268

Vert. Stab.

Position	Lat. Defl. + Left
V-1	$\bar{0}$.0352
V-2	$\bar{0}$.0282
V-3	$\bar{0}$.0282
V-4	$\bar{0}$.0352
V-5	$\bar{0}$.0282
V-6	$\bar{0}$.0310
V-7	$\bar{0}$.0239
V-8	$\bar{0}$.0254
V-9	$\bar{0}$.0085
V-10	$\bar{0}$.0211
V-11	0.0197
V-12	0.0535
V-13	0.0352
V-14	$\bar{0}$.0254
V-15	$\bar{0}$.0225
V-16	$\bar{0}$.0127
V-17	0.0042
F-25	$\bar{0}$.0084
F-26	$\bar{0}$.0170
F-27	$\bar{0}$.0196

Fuselage (WL 100)

Position	Lat. Defl. + Left	Ang. Defl. $X10^3$*
F-11-12	$\bar{0}$.0317	8.1690
F-13-14	0.0000	5.4930
F-15-16	$\bar{0}$.0352	2.0422
F-17-18	$\bar{0}$.1028	0.2817
F-19-20	$\bar{0}$.0056	$\bar{1}$.1690
F-21-22	0.0190	$\bar{1}$.4789
F-23-24	0.0120	$\bar{1}$.1268
F-25-30	$\bar{0}$.0084	$\bar{0}$.7746
F-26-31	$\bar{0}$.0169	$\bar{0}$.3662
F-27-32	$\bar{0}$.0197	0.2535

Wing Fan

Position	Vert. Defl. + Up
LWF-1	0.1408
LWF-2	0.2817
LWF-3	0.5634
LWF-4	0.1408

Aileron

Position	Vert. Defl. + Up
LA-1	$\bar{0}$.4648
LA-2	0.5930
LA-3	$\bar{0}$.2676
LA-4	0.7310
LA-5	$\bar{0}$.0831
LA-6	0.8648
LA-7	0.1408
LA-8	0.7930
LA-9	0.2282
LA-10	0.9268
LA-11	0.2676
LA-12	1.0000

Elevator

Position	Vert. Defl. + Up
LE-1	0.0423
LE-2	0.0592
LE-3	0.0296
LE-4	0.0465
LE-5	0.0127
LE-6	0.0296
LE-7	0.0042
LE-8	0.0183
LE-9	0.0028
LE-10	0.0056
LE-11	0.0014
LE-12	0.0014

Rudder

Position	Lat. Defl. + Left
R-1	0.0845
R-2	0.0704
R-3	0.0423
R-4	0.0169
R-5	0.0190
R-6	$\bar{0}$.0085
R-7	0.0169
R-8	$\bar{0}$.0141
R-9	0.0141
R-10	$\bar{0}$.0239
R-11	0.0113
R-12	$\bar{0}$.0282

* Left Wing Down

TABLE 21

ANTISYMMETRIC MODE SHAPE
MODE 8
f = 36.8 cps g = 0.058

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)		
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10^3*
LW-1	$\bar{0}.4602$	LH-1	0.0722	V-1	$\bar{0}.0266$	F-11-12	$\bar{0}.0030$	$\bar{3}.9549$
LW-2	$\bar{0}.4211$	LH-2	0.1496	V-2	$\bar{0}.0239$	F-13-14	$\bar{0}.0075$	$\bar{2}.5865$
LW-3	$\bar{0}.3489$	LH-3	0.0481	V-3	$\bar{0}.0244$	F-15-16	0.0038	$\bar{1}.4436$
LW-4	$\bar{0}.4421$	LH-4	0.1119	V-4	$\bar{0}.0203$	F-17-18	0.0153	$\bar{1}.0226$
LW-5	$\bar{0}.3263$	LH-5	0.0286	V-5	$\bar{0}.0211$	F-19-20	0.0234	$\bar{0}.6015$
LW-6	$\bar{0}.2241$	LH-6	0.0785	V-6	$\bar{0}.0081$	F-21-22	0.0195	$\bar{0}.4511$
LW-7	$\bar{0}.4015$	LH-7	$\bar{0}.0180$	V-7	$\bar{0}.0147$	F-23-24	0.0111	$\bar{0}.4211$
LW-8	$\bar{0}.2481$	LH-8	0.0120	V-8	0.0095	F-25-30	0.0000	$\bar{0}.4060$
LW-9	$\bar{0}.1158$	LH-9	0.0492	V-9	$\bar{0}.0038$	F-26-31	$\bar{0}.0099$	$\bar{0}.3759$
LW-10	$\bar{0}.3459$	LH-10	$\bar{0}.0271$	V-10	0.0331	F-27-32	$\bar{0}.0218$	$\bar{0}.3759$
LW-11	$\bar{0}.1955$	LH-11	0.0241	V-11	0.0105		Wing Fan	
LW-12	$\bar{0}.0278$	LH-19	$\bar{0}.0015$	V-12	0.0233		Position	Vert. Defl. + Up
LW-13	$\bar{0}.2767$		Lat. Defl. + Left	V-13	0.0611		LWF-1	0.0331
LW-14	$\bar{0}.1534$			V-14	$\bar{0}.0195$		LWF-2	0.1008
LW-15	0.0406	LH-12	0.0707	V-15	$\bar{0}.0090$		LWF-3	0.1128
LW-16	$\bar{0}.1910$	LH-13	0.0586	V-16	0.0060		LWF-4	0.0526
LW-17	0.0992	LH-20	0.0662	V-17	0.0263			
LW-18	$\bar{0}.1128$		F & A Defl. + Aft	F-25	0			
LW-19	0.1248			F-26	$\bar{0}.0099$			
LW-20	$\bar{0}.0496$	LH-14	0.0074	F-27	$\bar{0}.0221$			
LW-21	0.1158	LH-15	0.0132					
LW-22	–	LH-16	0.0192					
LW-23	–	LH-17	0.0251					
	F & A Defl. + Aft	LH-18	0.0311					
LW-24	0.0502							
LW-25	0.0400							
LW-26	0.0299							
LW-27	0.0182							

Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LA-1	$\bar{0}.2481$	LE-1	0.1624	R-1	0.0301
LA-2	0.7669	LE-2	0.1609	R-2	0.0221
LA-3	$\bar{0}.1504$	LE-3	0.1429	R-3	0.0030
LA-4	0.8481	LE-4	0.1368	R-4	0.0015
LA-5	$\bar{0}.0586$	LE-5	0.1068	R-5	$\bar{0}.0150$
LA-6	0.9233	LE-6	0.0977	R-6	$\bar{0}.0134$
LA-7	0.0526	LE-7	0.0782	R-7	$\bar{0}.0211$
LA-8	0.8662	LE-8	0.0677	R-8	$\bar{0}.0195$
LA-9	0.1278	LE-9	0.0376	R-9	$\bar{0}.0316$
LA-10	0.9459	LE-10	0.0286	R-10	$\bar{0}.0286$
LA-11	0.1729	LE-11	0.0150	R-11	$\bar{0}.0361$
LA-12	1.0000	LE-12	0.0060	R-12	$\bar{0}.0331$

* Left Wing Down

TABLE 22

ANTISYMMETRIC MODE SHAPE
MODE 9
f = 44.6 cps g = 0.063

Wing

Position	Vert. Defl. + Up
LW-1	0.0796
LW-2	$\bar{0}$.0980
LW-3	$\bar{0}$.1099
LW-4	0.1619
LW-5	$\bar{0}$.0680
LW-6	$\bar{0}$.1544
LW-7	0.2102
LW-8	$\bar{0}$.0299
LW-9	$\bar{0}$.1823
LW-10	0.2299
LW-11	$\underline{0}$.0156
LW-12	$\bar{0}$.1952
LW-13	0.2269
LW-14	$\underline{0}$.0673
LW-15	$\bar{0}$.1952
LW-16	$\underline{0}$.1996
LW-17	$\bar{0}$.1796
LW-18	$\underline{0}$.1565
LW-19	$\bar{0}$.1503
LW-20	$\underline{0}$.1068
LW-21	$\bar{0}$.1122
LW-22	—
LW-23	—
	F & A Defl. + Aft
LW-24	0.0258
LW-25	0.0206
LW-26	0.0154
LW-27	0.0093

Horiz. Stab.**

Position	Vert. Defl. + Up
LH-1	0.0135
LH-2	0.0122
LH-3	0.0109
LH-4	0.0097
LH-5	0.0088
LH-6	0.0080
LH-7	0.0126
LH-8	0.0076
LH-9	0.0068
LH-10	0.0126
LH-11	0.0061
LH-19	0.0068
	Lat. Defl. + Left
LH-12	0.0133
LH-13	0.0000
LH-20	0.0075
	F & A Defl. + Aft
LH-14	0.0143
LH-15	0.0136
LH-16	0.0129
LH-17	0.0122
LH-18	0.0116
RH-18	0.0190

Vert. Stab.

Position	Lat. Defl. + Left
V-1	0.0152
V-2	0.0151
V-3	0.0161
V-4	0.0173
V-5	0.0152
V-6	0.0174
V-7	0.0136
V-8	0.0152
V-9	0.0111
V-10	0.0110
V-11	0.0078
V-12	$\underline{0}$.0049
V-13	$\bar{0}$.0084
V-14	0.0154
V-15	0.0135
V-16	0.0094
V-17	$\underline{0}$.0033
F-25	$\bar{0}$.0069
F-26	0.0018
F-27	0.0178

Fuselage (WL 100)

Position	Lat. Defl. + Left	Ang. Defl. X10[3]*
F-11-12	$\bar{0}$.0286	4.0136
F-13-14	$\underline{0}$.0041	2.3129
F-15-16	$\bar{0}$.0109	1.0204
F-17-18	$\bar{0}$.0269	0.6803
F-19-20	$\bar{0}$.0086	0.4762
F-21-22	$\bar{0}$.0041	0.4762
F-23-24	$\bar{0}$.0105	0.4762
F-25-30	$\bar{0}$.0069	0.4422
F-26-31	0.0017	0.3401
F-27-32	0.0177	0.0680

Wing Fan

Position	Vert. Defl. + Up
LWF-1	$\underline{0}$.0354
LWF-2	$\bar{0}$.0292
LWF-3	$\bar{0}$.1007
LWF-4	$\bar{0}$.0184

Aileron

Position	Vert. Defl. + Up
LA-1	$\bar{0}$.0401
LA-2	$\underline{1}$.0000
LA-3	$\bar{0}$.1020
LA-4	$\underline{0}$.8844
LA-5	$\bar{0}$.1401
LA-6	$\underline{0}$.8503
LA-7	$\bar{0}$.1653
LA-8	$\underline{0}$.5510
LA-9	$\bar{0}$.1721
LA-10	$\underline{0}$.5660
LA-11	$\bar{0}$.1735
LA-12	0.5850

Elevator**

Position	Vert. Defl. + Up
LE-1	$\bar{0}$.0094
LE-2	$\bar{0}$.0141
LE-3	$\bar{0}$.0073
LE-4	$\bar{0}$.0080
LE-5	$\bar{0}$.0118
LE-6	$\bar{0}$.0067
LE-7	$\bar{0}$.0170
LE-8	$\bar{0}$.0107
LE-9	$\bar{0}$.0168
LE-10	$\bar{0}$.0129
LE-11	$\bar{0}$.0096
LE-12	$\bar{0}$.0061

Rudder

Position	Lat. Defl. + Left
R-1	0.0110
R-2	0.0116
R-3	0.0224
R-4	0.0238
R-5	0.0279
R-6	0.0291
R-7	0.0288
R-8	0.0296
R-9	0.0272
R-10	0.0269
R-11	0.0218
R-12	0.0199

* Left Wing Down

** Symmetric Response (essentially Elevator Bending with Response at higher frequency)

TABLE 23

ANTISYMMETRIC MODE SHAPE

Mode 10

f = 50.6 cps g = 0.033

Wing

Position	Vert. Defl. + Up
LW-1	0.0406
LW-2	0.0464
LW-3	0.0581
LW-4	0.0152
LW-5	0.0370
LW-6	0.0522
LW-7	$\bar{0}.0051$
LW-8	0.0283
LW-9	0.0450
LW-10	$\bar{0}.0203$
LW-11	0.0210
LW-12	0.0377
LW-13	$\bar{0}.0276$
LW-14	0.0145
LW-15	0.0319
LW-16	$\bar{0}.0290$
LW-17	0.0247
LW-18	$\bar{0}.0247$
LW-19	0.0174
LW-20	$\bar{0}.0189$
LW-21	0.0116
LW-22	—
LW-23	—
	F & A Defl. + Aft
LW-24	—
LW-25	—
LW-26	—
LW-27	—

Horiz. Stab.

Position	Vert. Defl. + Up
LH-1	$\bar{0}.1190$
LH-2	$\bar{0}.0697$
LH-3	$\bar{0}.1154$
LH-4	$\bar{0}.0813$
LH-5	$\bar{0}.1016$
LH-6	$\bar{0}.0827$
LH-7	$\bar{0}.0936$
LH-8	$\bar{0}.0813$
LH-9	$\bar{0}.0726$
LH-10	$\bar{0}.0552$
LH-11	$\bar{0}.0552$
LH-19	$\bar{0}.0493$
	Lat. Defl. + Left
LH-12	$\bar{0}.0827$
LH-13	$\bar{0}.0697$
LH-20	$\bar{0}.0755$
	F & A Defl. + Aft
LH-14	$\bar{0}.0083$
LH-15	$\bar{0}.0148$
LH-16	$\bar{0}.0215$
LH-17	$\bar{0}.0282$
LH-18	$\bar{0}.0348$

Vert. Stab.

Position	Lat. Defl. + Up
V-1	$\bar{0}.1611$
V-2	$\bar{0}.0610$
V-3	0.1451
V-4	$\bar{0}.1582$
V-5	0.1451
V-6	$\bar{0}.1654$
V-7	0.1596
V-8	$\bar{0}.1742$
V-9	0.2496
V-10	$\bar{0}.1858$
V-11	0.3019
V-12	0.2685
V-13	$\bar{0}.0435$
V-14	$\bar{0}.0552$
V-15	$\bar{0}.0435$
V-16	$\bar{0}.0268$
V-17	$\bar{0}.0203$
F-25	$\bar{0}.1045$
F-26	$\bar{0}.0369$
F-27	0.1546

Fuselage (WL 100)

Position	Lat. Defl. + Left	Ang. Defl. X10^3*
F-11-12	0.0241	$\bar{1}.4977$
F-13-14	$\bar{0}.0080$	$\bar{0}.2730$
F-15-16	$\bar{0}.0061$	0.5155
F-17-18	$\bar{0}.0232$	$\bar{0}.4139$
F-19-20	$\bar{0}.0813$	$\bar{2}.6392$
F-21-22	$\bar{0}.1248$	$\bar{3}.4833$
F-23-24	$\bar{0}.1379$	$\bar{3}.5254$
F-25-30	$\bar{0}.1045$	$\bar{3}.1640$
F-26-31	$\bar{0}.0363$	$\bar{2}.6415$
F-27-32	0.1559	$\bar{1}.8142$

Wing Fan

Position	Vert. Defl. + Up
LWF-1	—
LWF-2	$\bar{0}.0145$
LWF-3	$\bar{0}.0203$
LWF-4	$\bar{0}.0145$

Aileron

Position	Vert. Defl. + Up
LA-1	0.0218
LA-2	$\bar{0}.0464$
LA-3	0.0174
LA-4	$\bar{0}.0552$
LA-5	0.0123
LA-6	$\bar{0}.0631$
LA-7	0.0058
LA-8	$\bar{0}.0726$
LA-9	0.0029
LA-10	$\bar{0}.0784$
LA-11	0.0014
LA-12	$\bar{0}.0827$

Elevator

Position	Vert. Defl. + Up
LE-1	$\bar{0}.0817$
LE-2	$\bar{0}.1023$
LE-3	$\bar{0}.0871$
LE-4	$\bar{0}.1103$
LE-5	$\bar{0}.0929$
LE-6	$\bar{0}.1161$
LE-7	$\bar{0}.0856$
LE-8	$\bar{0}.1045$
LE-9	$\bar{0}.0544$
LE-10	$\bar{0}.0639$
LE-11	$\bar{0}.0247$
LE-12	$\bar{0}.0283$

Rudder

Position	Lat. Defl. + Left
R-1	0.4717
R-2	0.4572
R-3	0.8926
R-4	0.8708
R-5	1.0000
R-6	0.9826
R-7	0.9564
R-8	0.9434
R-9	0.7141
R-10	0.7083
R-11	0.2758
R-12	0.2758

* Left Wing Down

TABLE 24

ANTISYMMETRIC MODE SHAPE
MODE 11
f = 72.9 cps g = 0.025

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10[3]*	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	–	LH-1	1.0000	V-1	–	F-11-12	–	–	LA-1	–	LE-1	$\bar{0}$.6163	R-1	0.0163
LW-2	–	LH-2	$\bar{0}$.3243	V-2	–	F-13-14	–	–	LA-2	–	LE-2	$\bar{0}$.4084	R-2	0.0074
LW-3	–	LH-3	0.6082	V-3	–	F-15-16	–	–	LA-3	–	LE-3	$\bar{0}$.8292	R-3	$\bar{0}$.0129
LW-4	–	LH-4	$\bar{0}$.4611	V-4	–	F-17-18	–	–	LA-4	–	LE-4	$\bar{0}$.6287	R-4	$\bar{0}$.0124
LW-5	–	LH-5	0.3126	V-5	–	F-19-20	–	–	LA-5	–	LE-5	$\bar{0}$.9530	R-5	$\bar{0}$.0262
LW-6	–	LH-6	$\bar{0}$.5027	V-6	–	F-21-22	–	–	LA-6	–	LE-6	$\bar{0}$.6510	R-6	$\bar{0}$.0226
LW-7	–	LH-7	0.3490	V-7	–	F-23-24	–	–	LA-7	–	LE-7	$\bar{0}$.7871	R-7	$\bar{0}$.0282
LW-8	–	LH-8	0.1134	V-8	–	F-25-30	–	–	LA-8	–	LE-8	$\bar{0}$.5248	R-8	$\bar{0}$.0248
LW-9	–	LH-9	$\bar{0}$.4488	V-9	–	F-26-31	–	–	LA-9	–	LE-9	$\bar{0}$.4156	R-9	$\bar{0}$.0228
LW-10	–	LH-10	0.1656	V-10	–	F-27-32	–	–	LA-10	–	LE-10	$\bar{0}$.2030	R-10	$\bar{0}$.0208
LW-11	–	LH-11	$\bar{0}$.2995	V-11	–		Wing Fan		LA-11	–	LE-11	$\bar{0}$.1485	R-11	$\bar{0}$.0079
LW-12	–	LH-19	0.0104	V-12	–		Position	Vert. Defl. + Up	LA-12	–	LE-12	0.0545	R-12	$\bar{0}$.0032
LW-13	–		Lat. Defl. + Left	V-13	–									
LW-14	–			V-14	–		LWF-1	–						
LW-15	–	LH-12	$\bar{0}$.0396	V-15	–		LWF-2	–						
LW-16	–	LH-13	0.0223	V-16	–		LWF-3	–						
LW-17	–	LH-20	$\bar{0}$.0146	V-17	–		LWF-4	–						
LW-18	–		F & A Defl. + Aft	F-25	–									
LW-19	–			F-26	–									
LW-20	–	LH-14	–	F-27	–									
LW-21	–	LH-15	–											
LW-22	–	LH-16	–											
LW-23	–	LH-17	–											
	F & A Defl. + Aft	LH-18	–											
LW-24	–													
LW-25	–													
LW-26	–													
LW-27	–													

* Left Wing Down

TABLE 25

PRIMARY CONTROL SYSTEMS RESONANCES
CTOL MODE

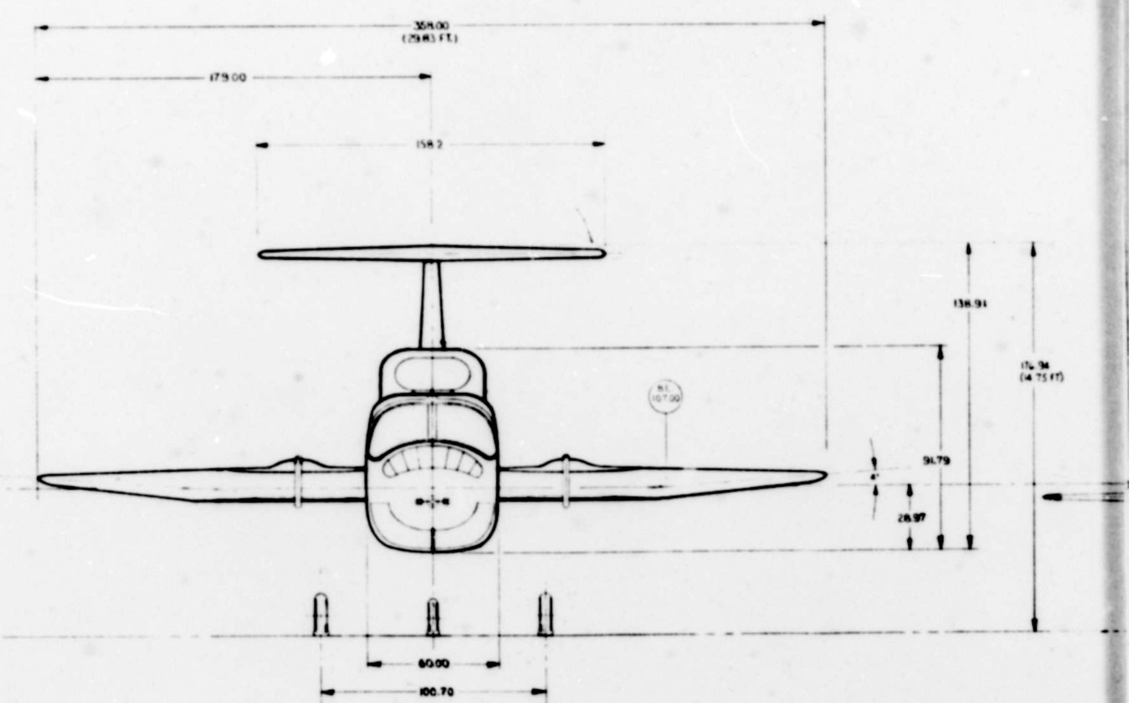
Component	Degrees of Freedom	Sense of Excitation	Location of Excitation	Frequency cps	Damping (g)	Remarks
Aileron System	Aileron Rotation Flight Tab Rotation Stick Rotation	Antisymmetric	Stick (A-CP)	48.6 92.3	-- —	
	Aileron Rotation Flight Tab Rotation	Antisymmetric	Aileron (LA-12) (RA-12)	42.1 —	— —	Inconclusive
	Aileron Rotation Flight Tab Rotation	Symmetric	Aileron (LA-12) (RA-12)	43.6 79.1	—	
	Aileron Rotation	Antisymmetric	Aileron (LA-12) (RA-12)	42.9*	—	
	Aileron Rotation	Antisymmetric	Aileron (LA-12) (RA-12)	40.5*	—	Single Hydraulic System
	Aileron Rotation	Symmetric	Aileron (LA-12) (RA-12)	42.9*	—	
	Aileron Rotation	Symmetric	Aileron (LA-12) (RA-12)	40.2*	—	Single Hydraulic System
	Flight Tab Rotation	Antisymmetric	Tab (LAT-4) (RAT-4)	—	—	Inconclusive
	Flight Tab Rotation	Symmetric	Tab (LAT-4) (RAT-4)	—	—	Inconclusive
Elevator System	Horizontal Tail Rotation Elevator Rotation Stick Rotation	Symmetric	Stick (E-CP)	— 18.3	— —	Inconclusive
	Horizontal Tail Rotation Elevator Rotation	Symmetric	Elevator (LE-10) (RE-10)	— 24.1	— —	Inconclusive
	Elevator Rotation	Antisymmetric	Elevator (LE-10) (RE-10)	—	—	Inconclusive
Rudder System	Rudder Rotation Trim Tab Rotation Pedal Rotation	—	Pedal (R-CP)	17.0 —	— —	 Inconclusive
	Rudder Rotation Trim Tab Rotation	—	Rudder (R-9)	— —		Inconclusive Inconclusive
	Rudder Rotation	—	Rudder (R-11)	7.3	—	
	Trim Tab Rotation	—	Tab (RT-3)	—	—	Inconclusive

*Average of Left and Right Ailerons

TABLE 26

MISCELLANEOUS COMPONENT RESONANCES

COMPONENT	POSITION	POINT OF EXCITATION	EXCITATION FORCE POUNDS	ROTATIONAL FREQUENCY cps	DAMPING (g)
Pitch Fan Doors	Forward Stick (43°)	NFD-2	10	17.9	.203
Pitch Fan Doors	Neutral Stick (77°)	NFD-2	10	12.8	.101
Pitch Fan Doors	Aft Stick (92°)	NFD-2	10	13.9	.270
Flaps	Streamwise (0°)	FL-2	5	56.3	High
Flaps	Fully Extended (45°)	FL-2	5	42.7	.082
Wing Fan Door	Fully Open (90°)	WFD-5	5	19.4	High
Thrust Spoilers		Between TS-1 and TS-2	3	70.9	.077


358.00
(29.83 FT.)
179.00
158.2
B.L.
107.00
138.91
176.91
(14.75 FT)
91.79
4°
28.97
60.00
100.70

A

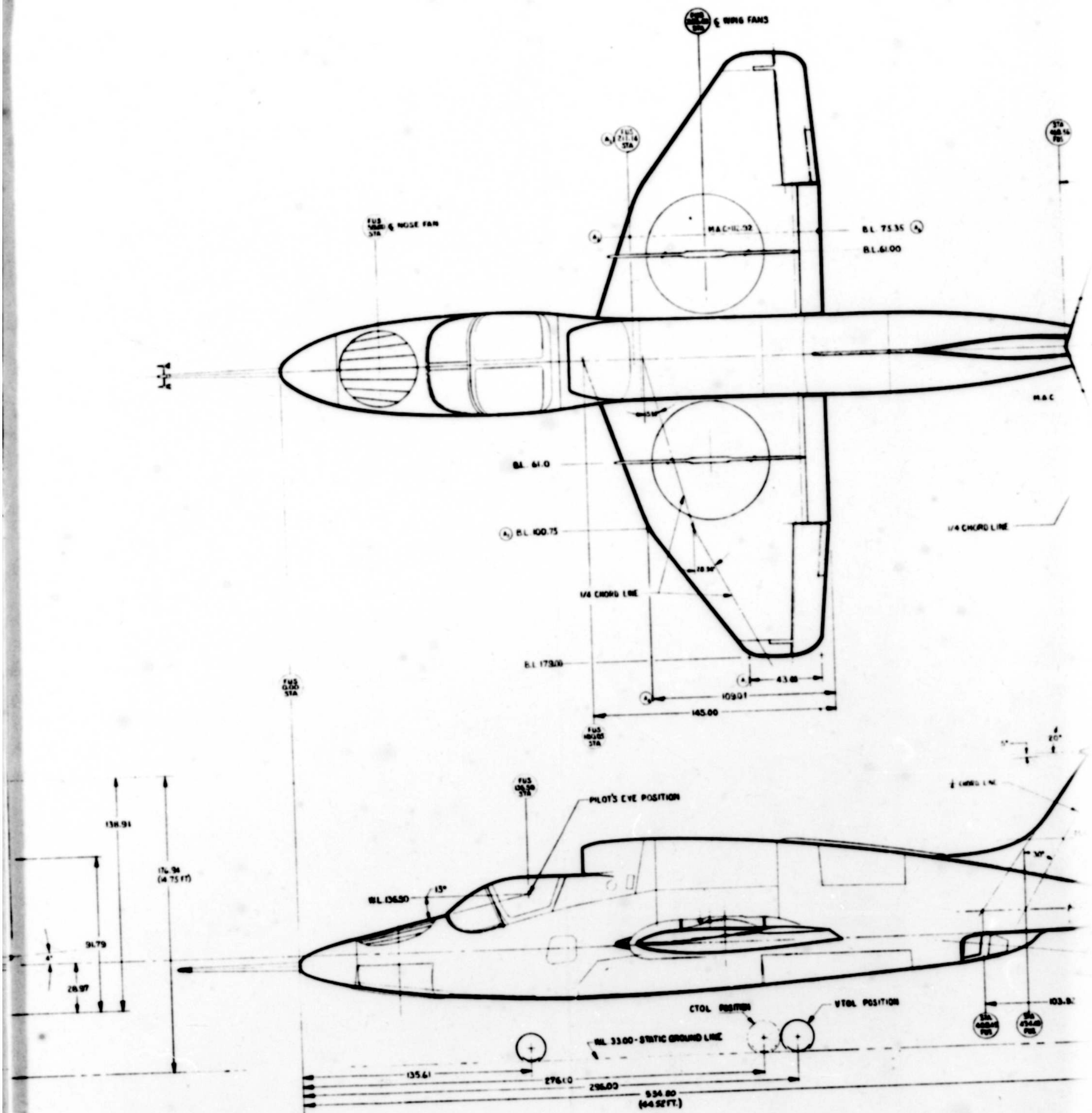


Figure 1 General Arra

B

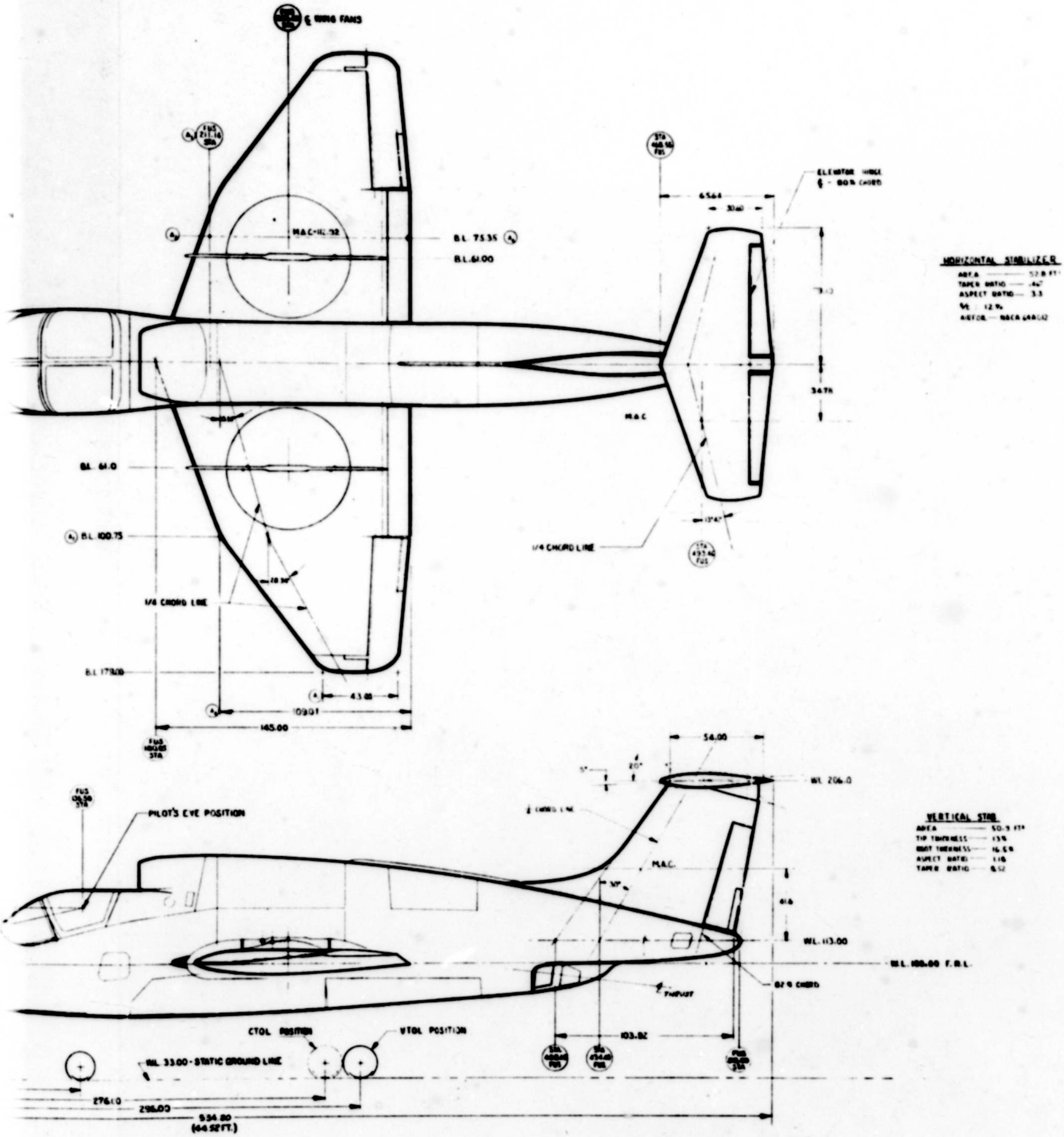


Figure 1 General Arrangement - XV-5A

C

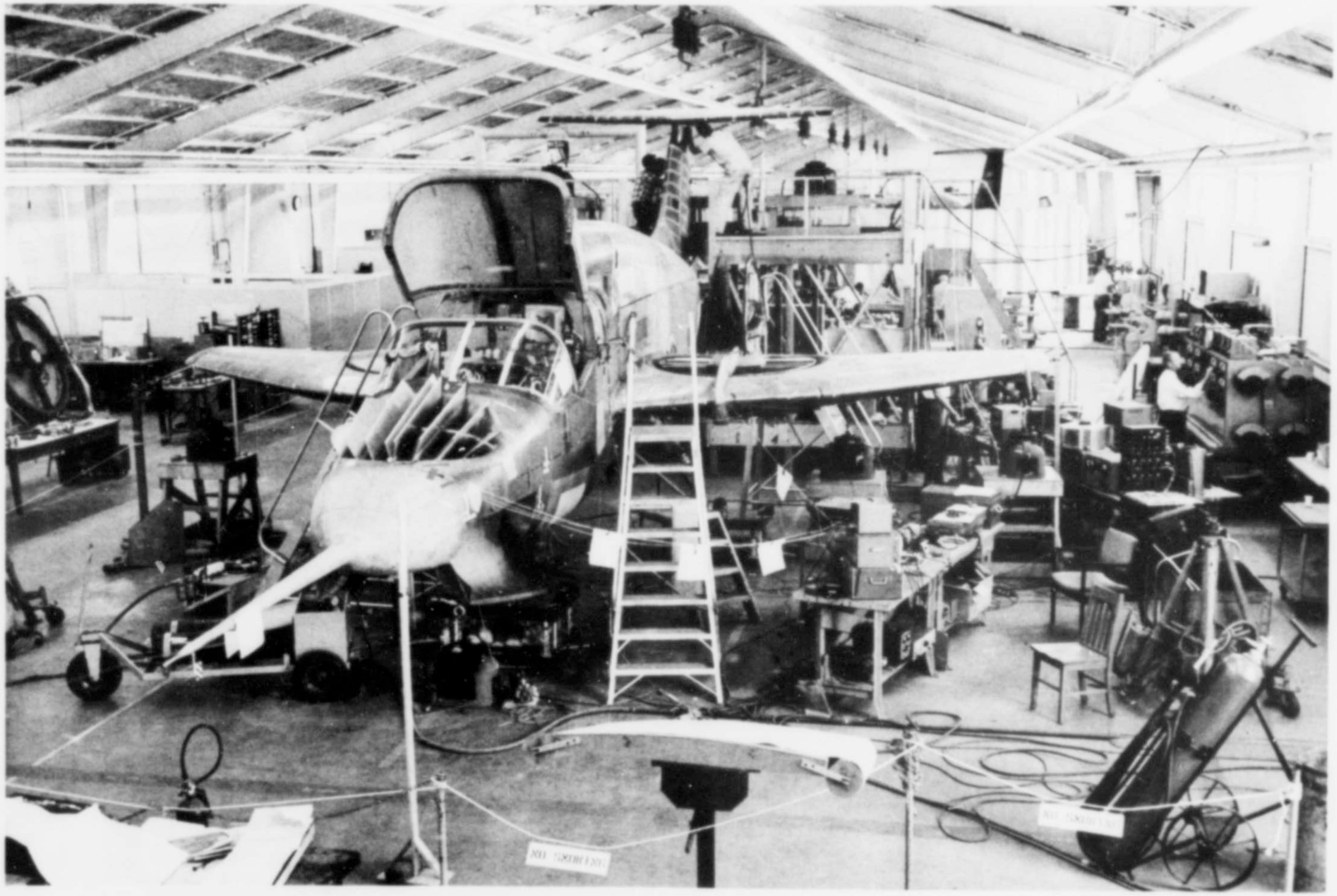


Figure 2 Airplane in Test Position Undergoing Final Test Preparation

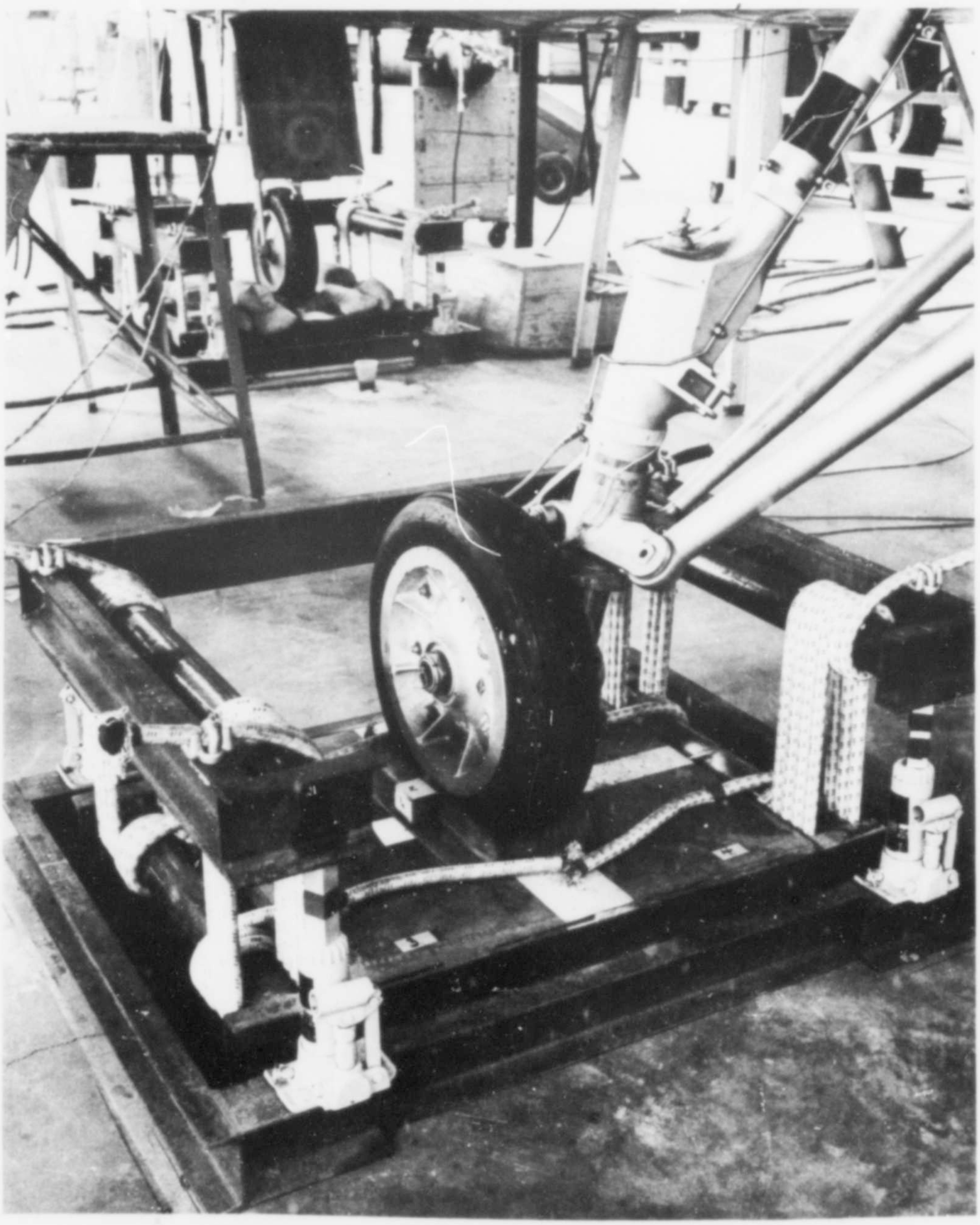


Figure 3 Details of Airplane Suspension System

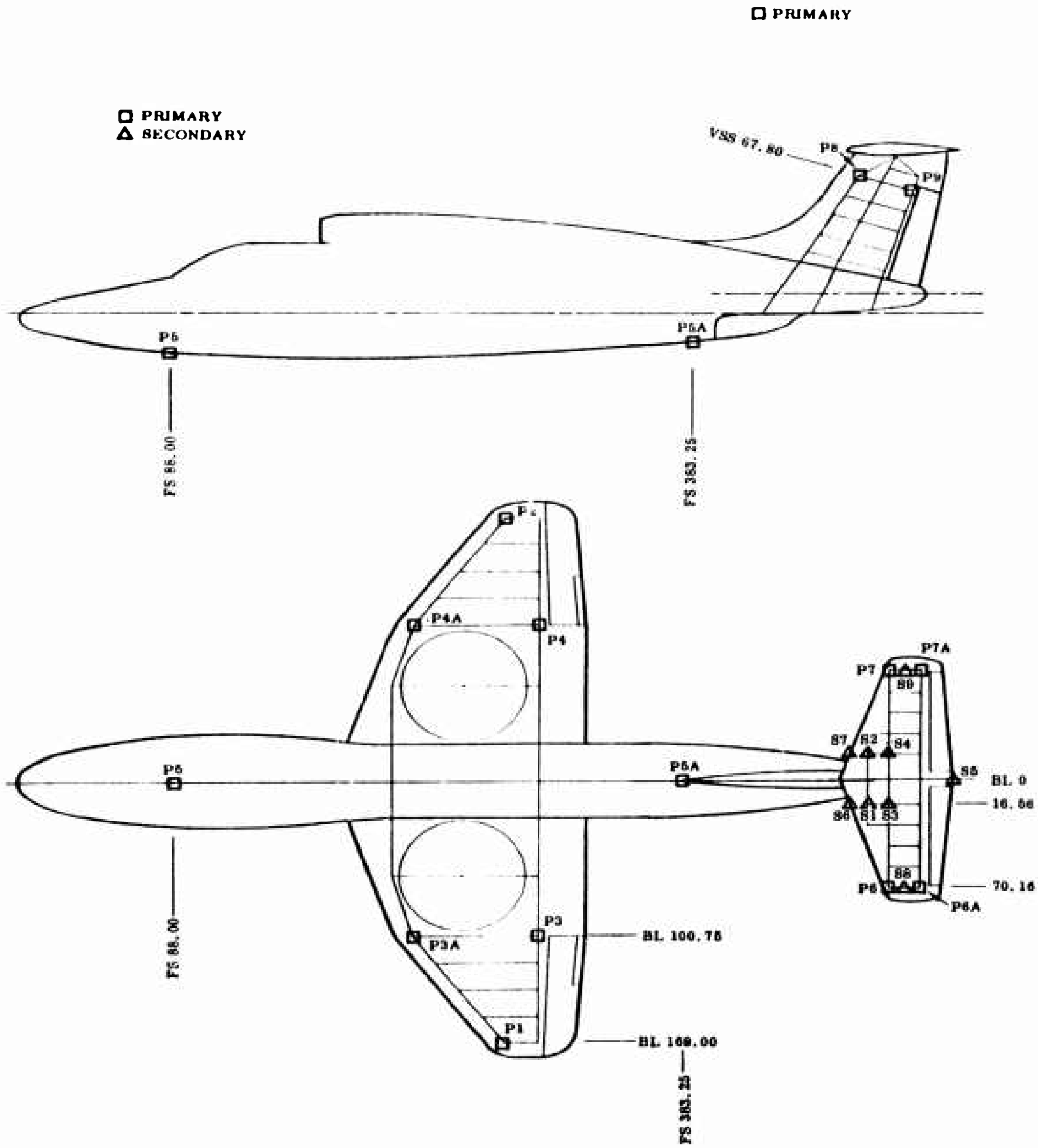


Figure 4. Shaker Locations

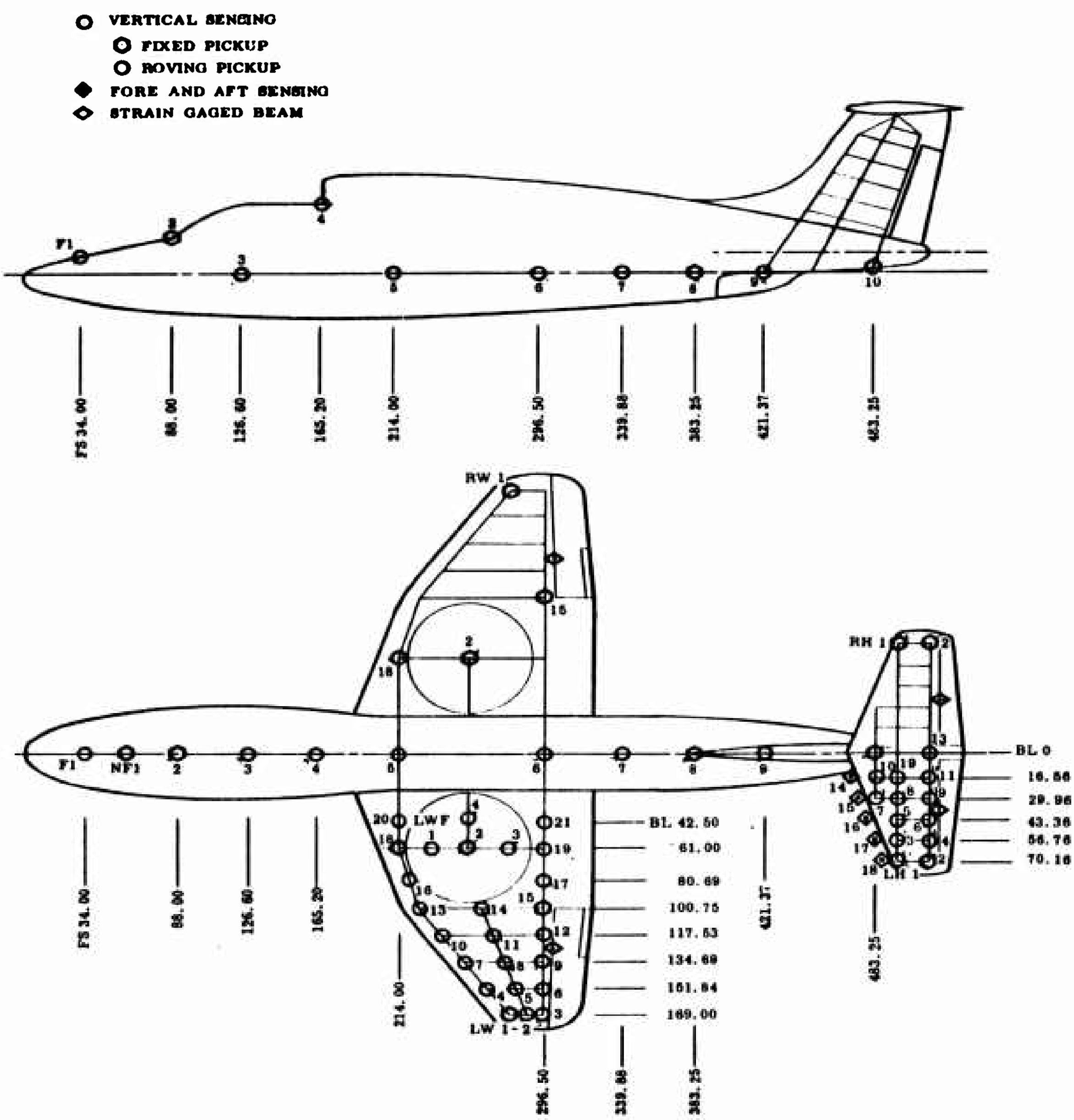


Figure 5. Symmetric Pickup Locations

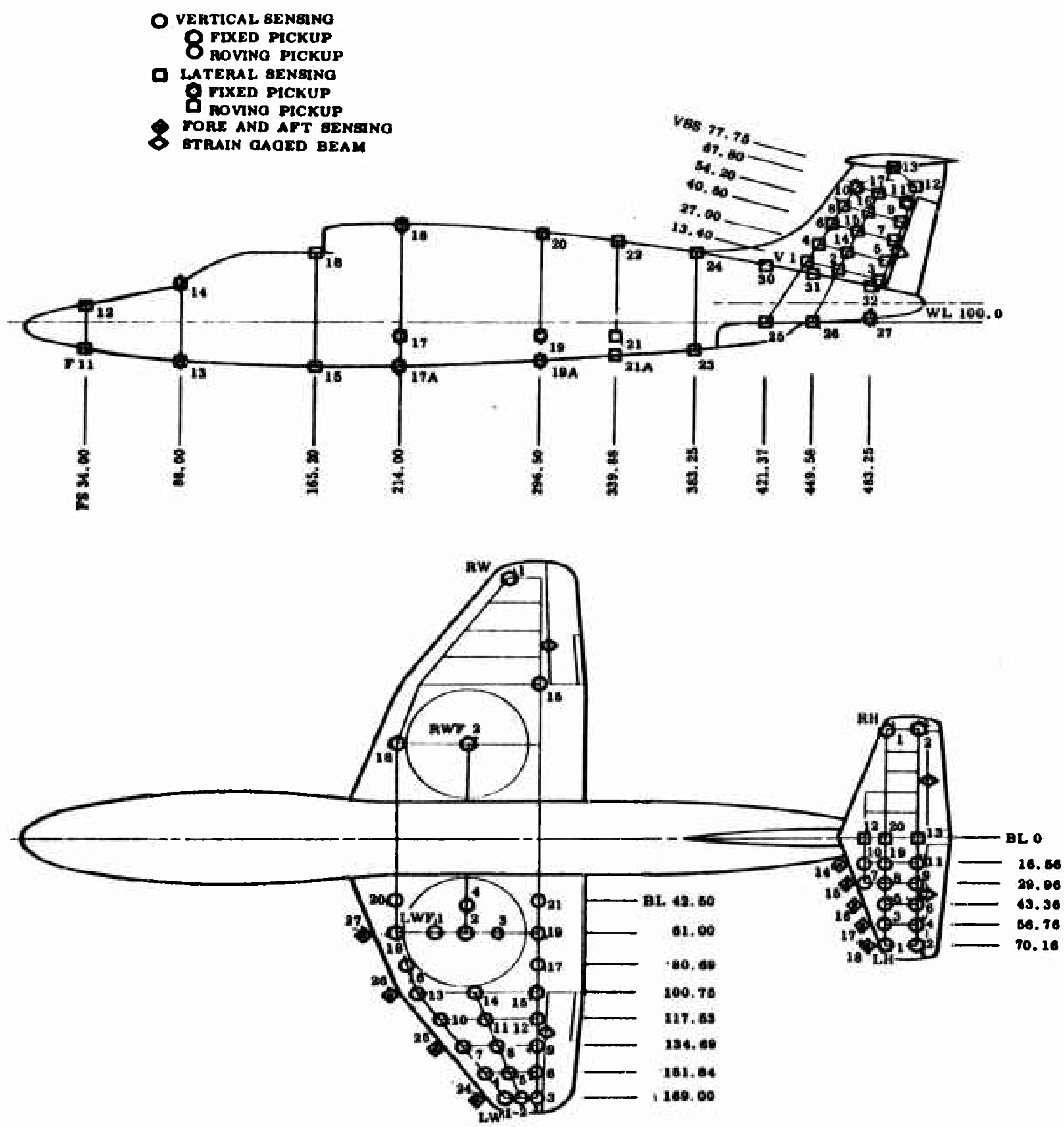


Figure 6 Antisymmetric Pickup Locations

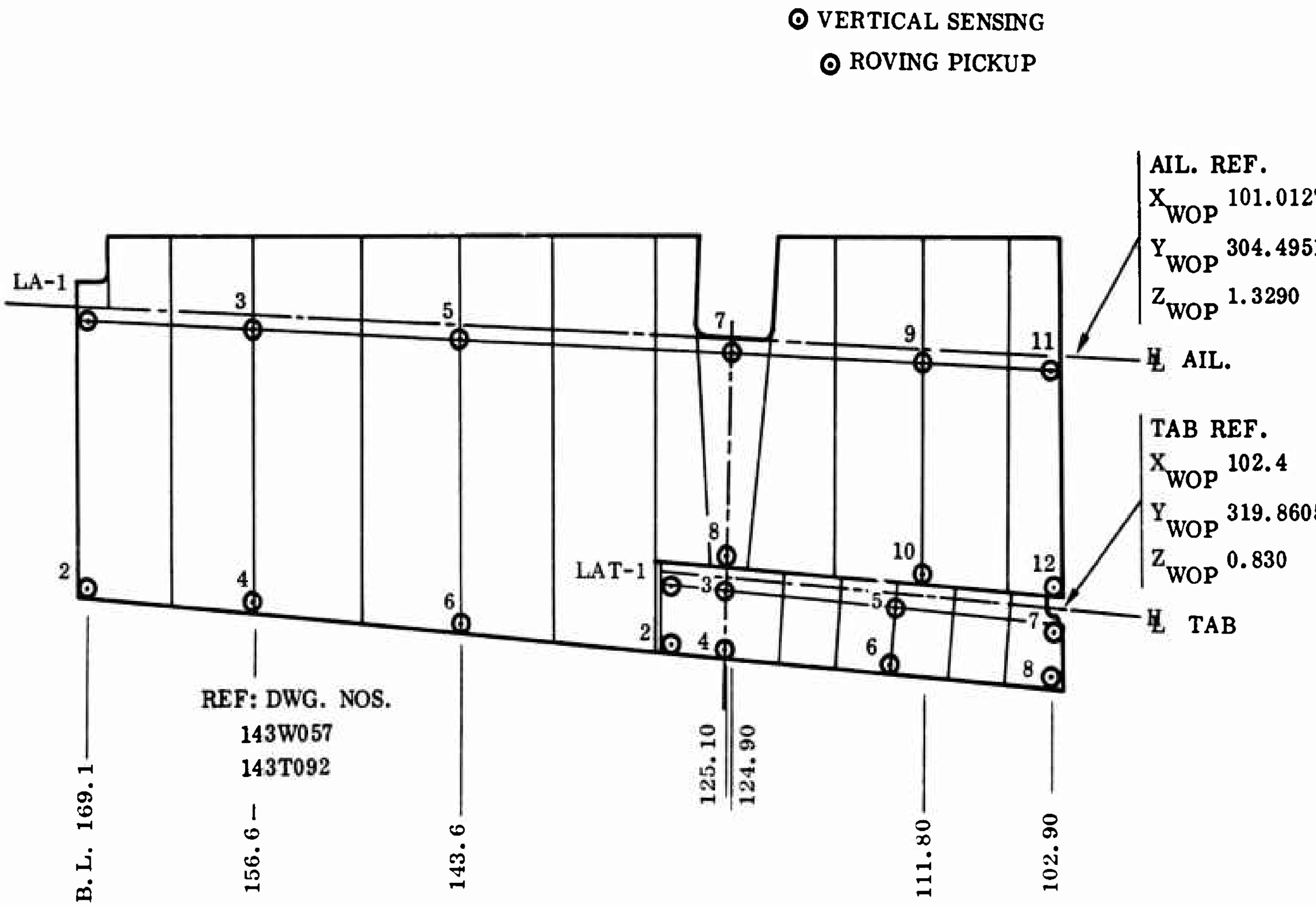


Figure 7. Control Surface Pickup Locations - Aileron and Aileron Tab

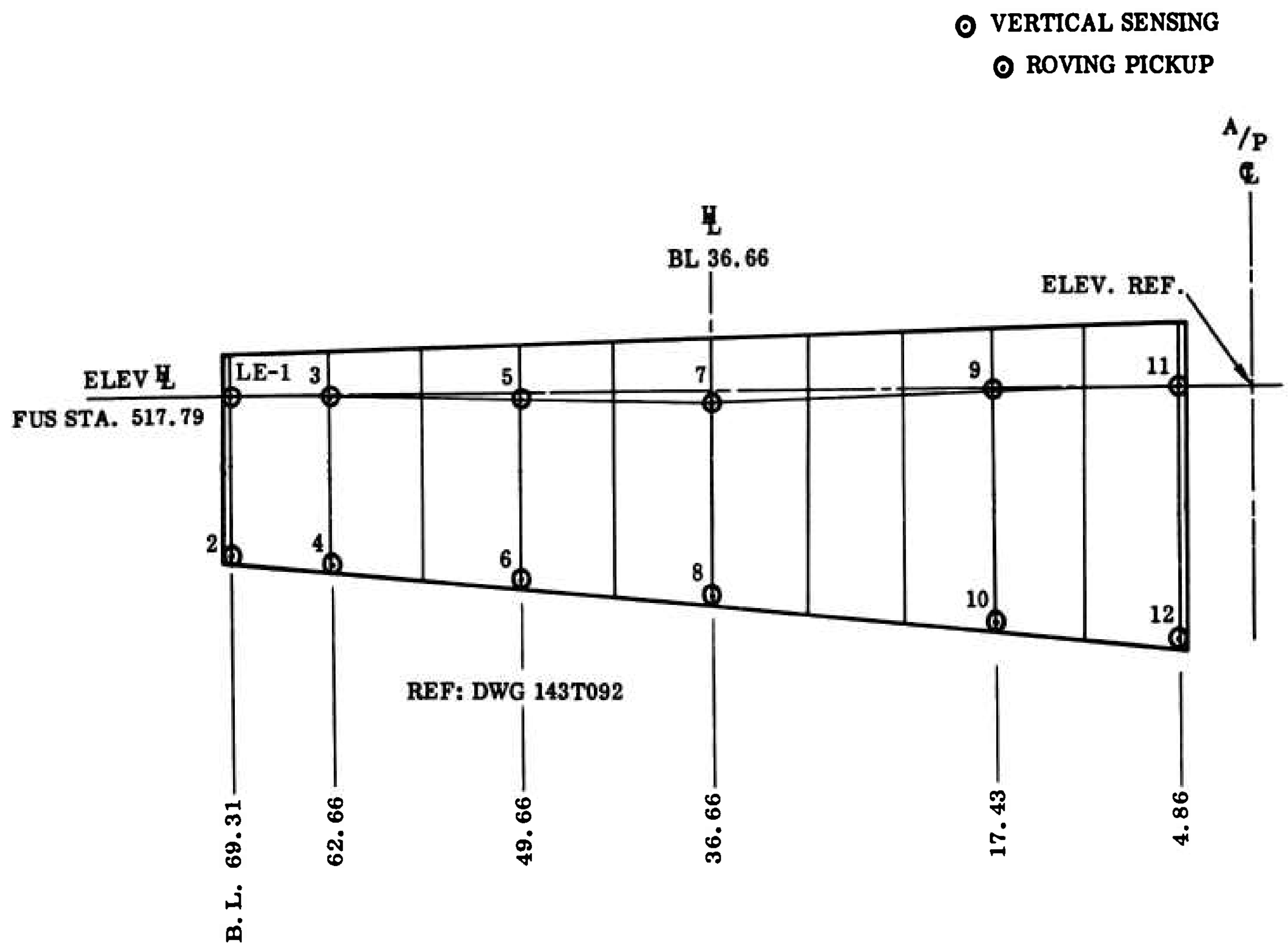
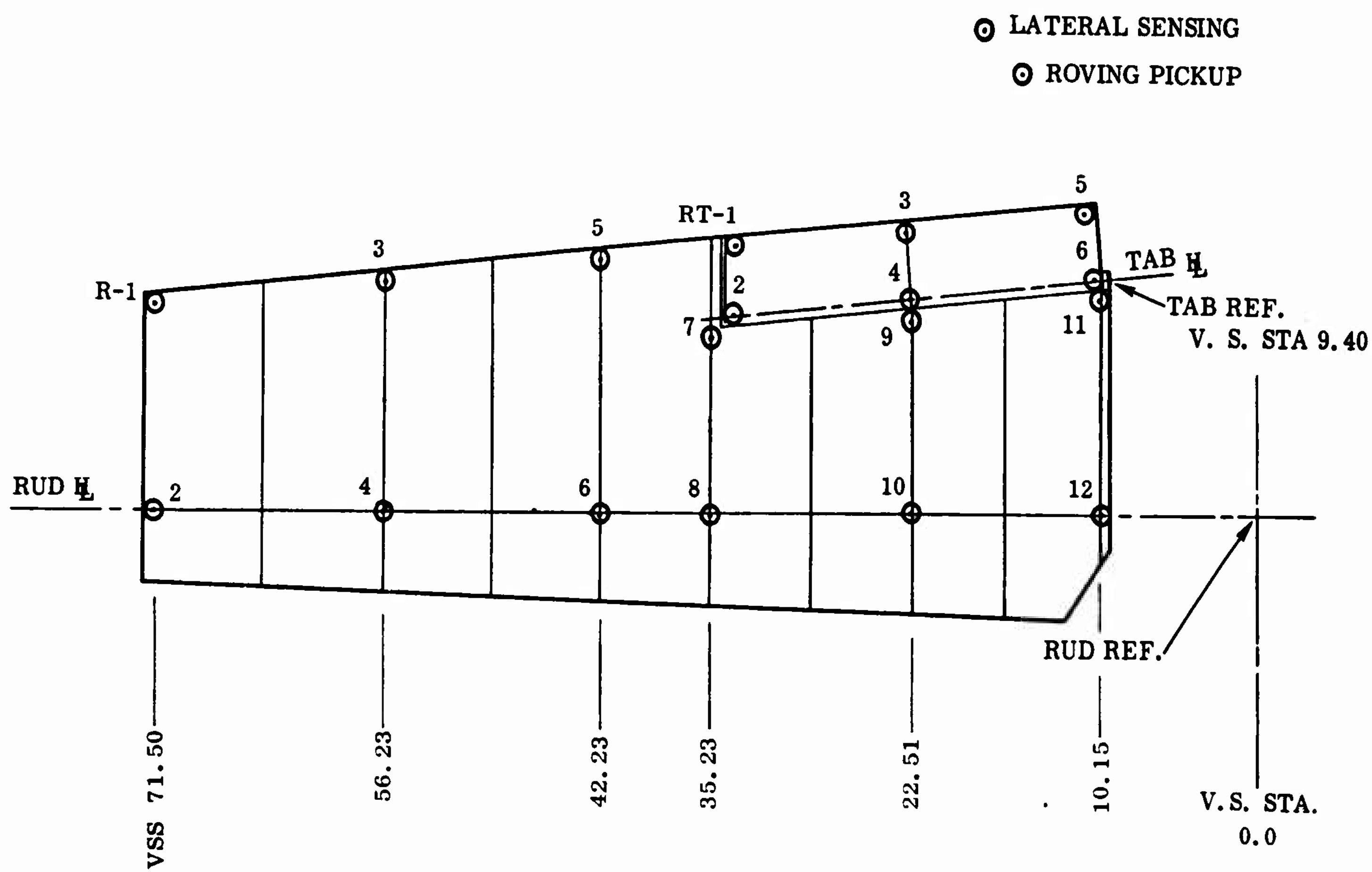


Figure 8. Control Surface Pickup Locations - Elevator



REF: DWG 143T050 AND 143T053

Figure 9 Control Surface Pickup Locations - Rudder and Rudder Tab

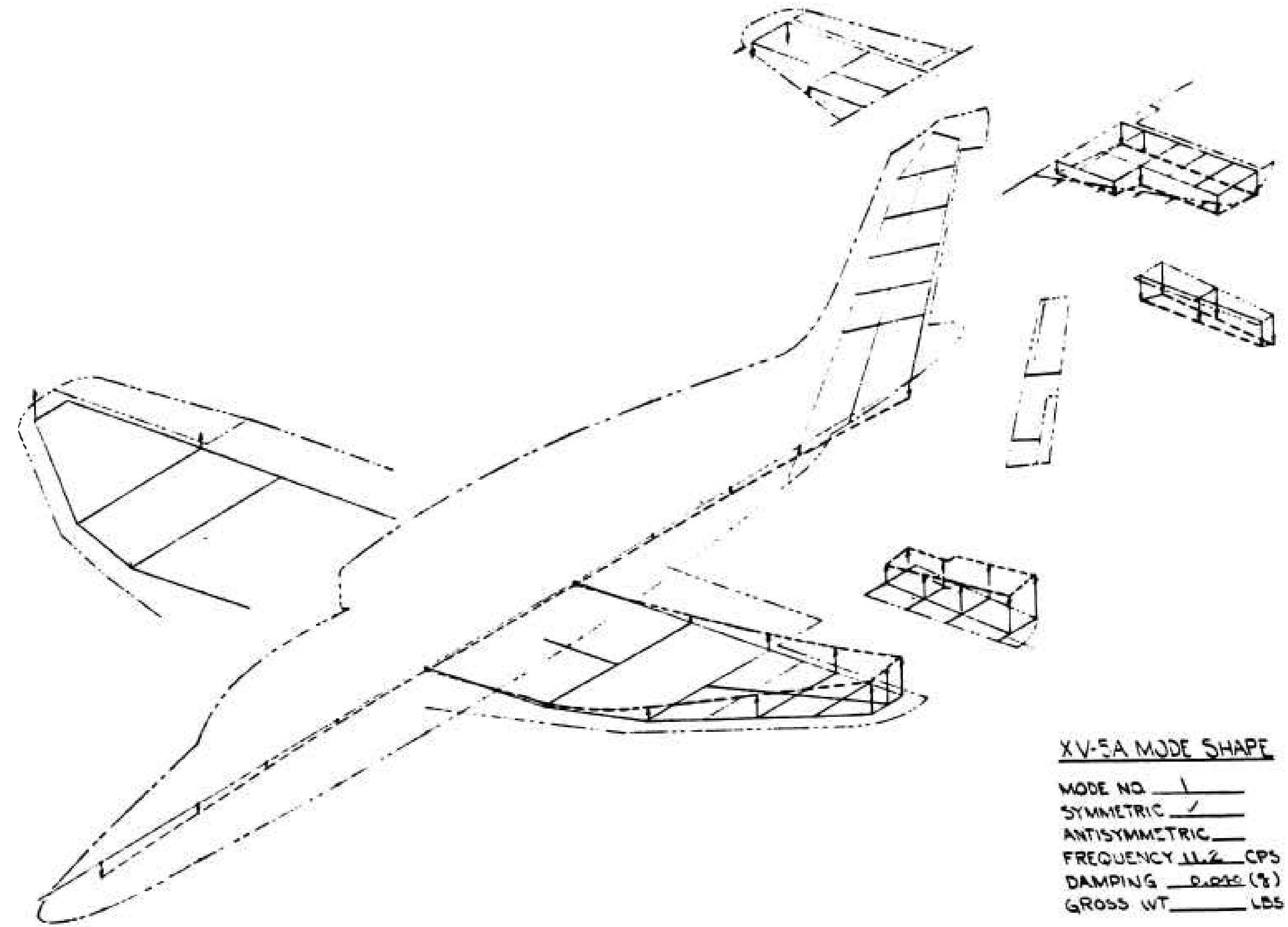


Figure 10 XV-5A Mode Shape - Mode No. 1

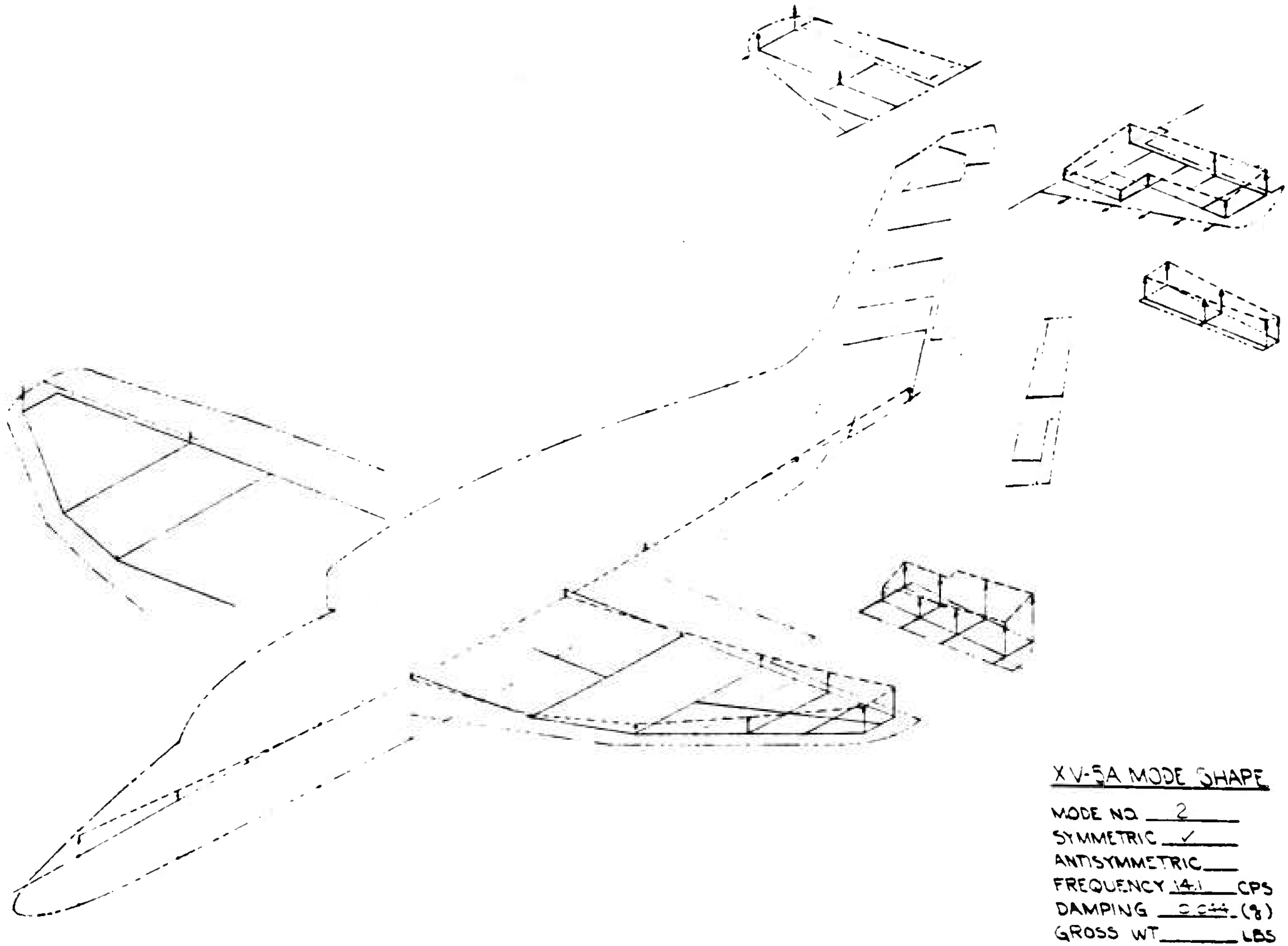


Figure 11   XV-5A Mode Shape - Mode No. 2

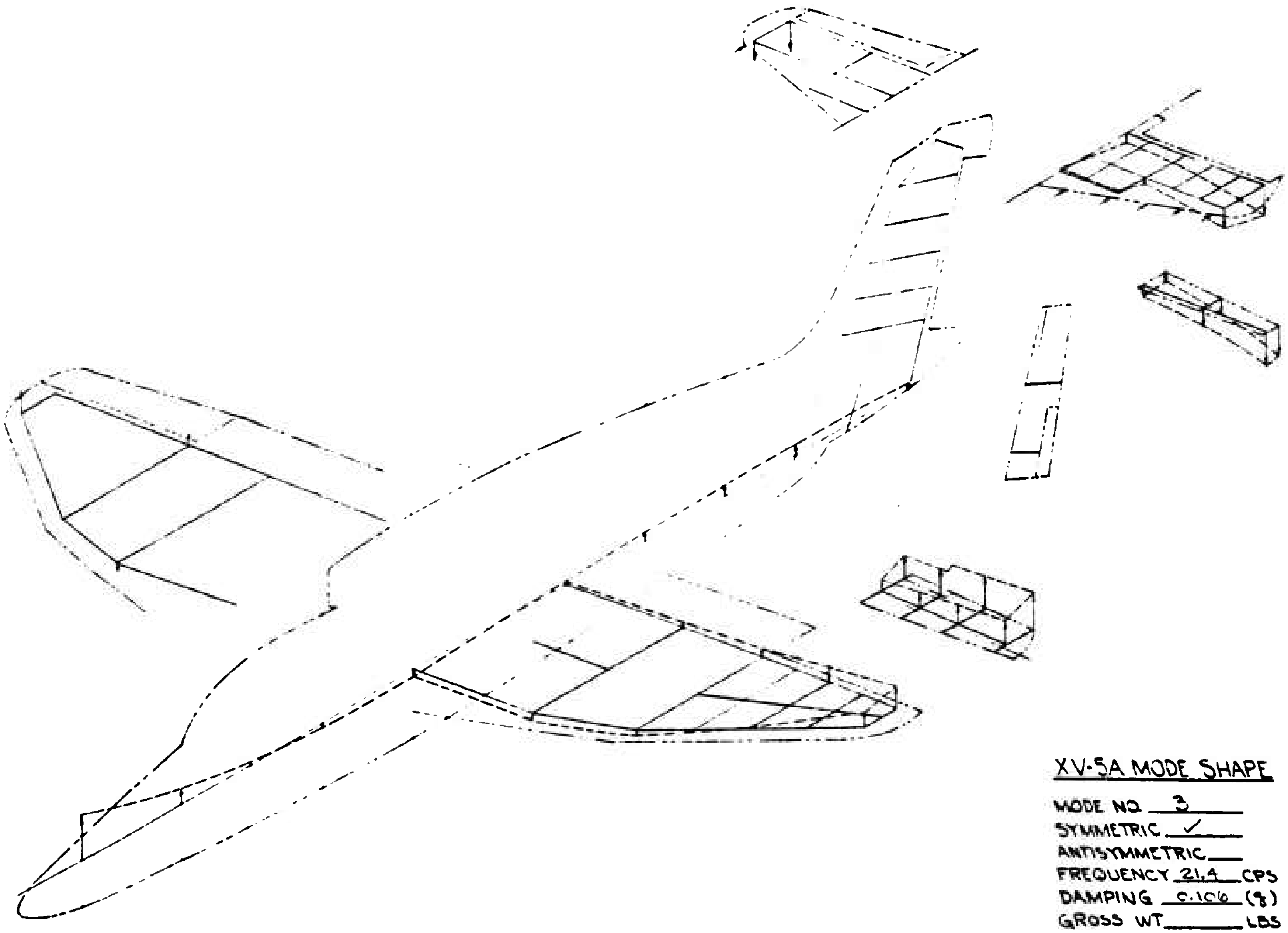


Figure 12 XV-5A Mode Shape - Mode No. 3

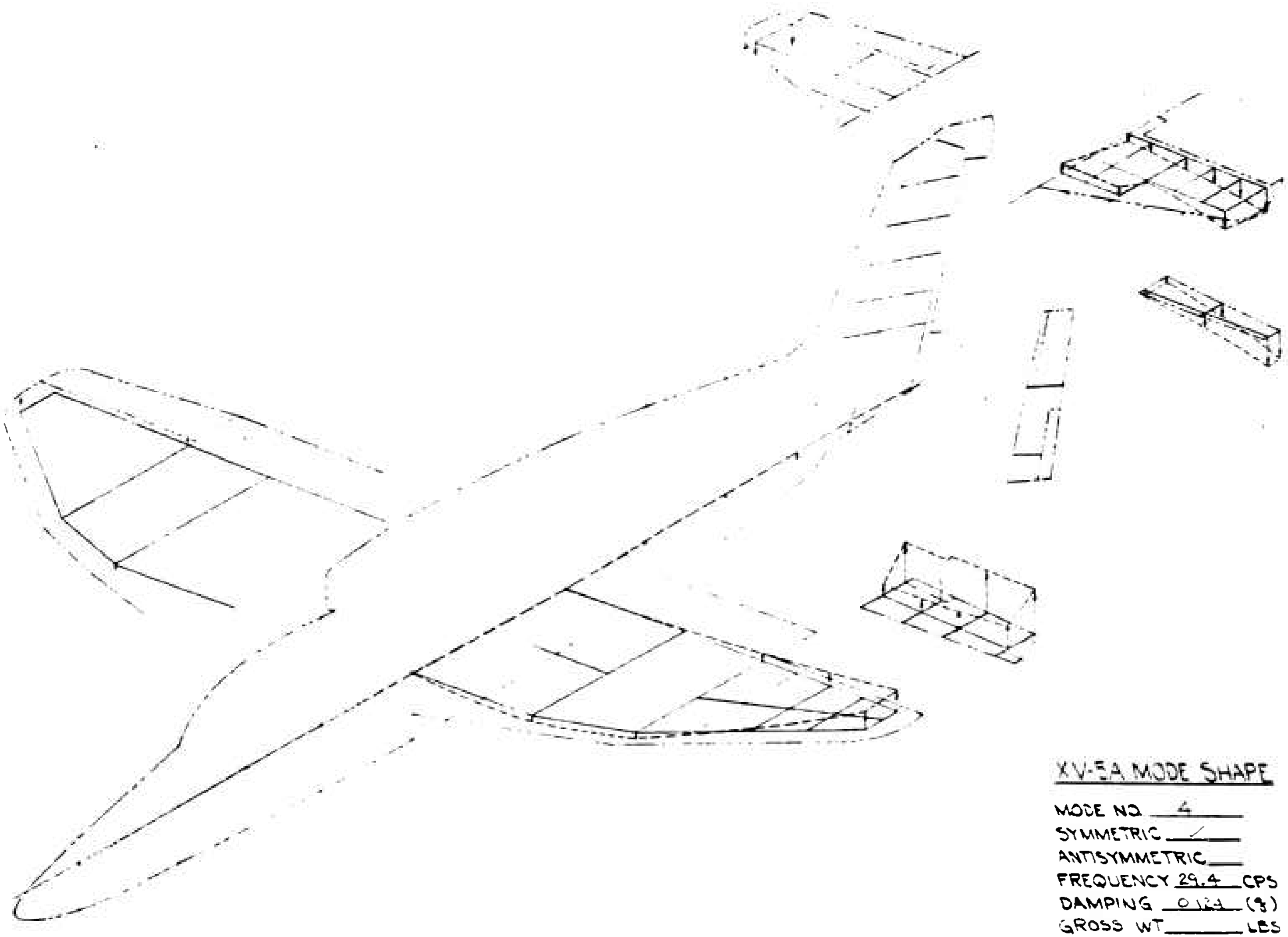


Figure 13 XV-5A Mode Shape - Mode No. 4

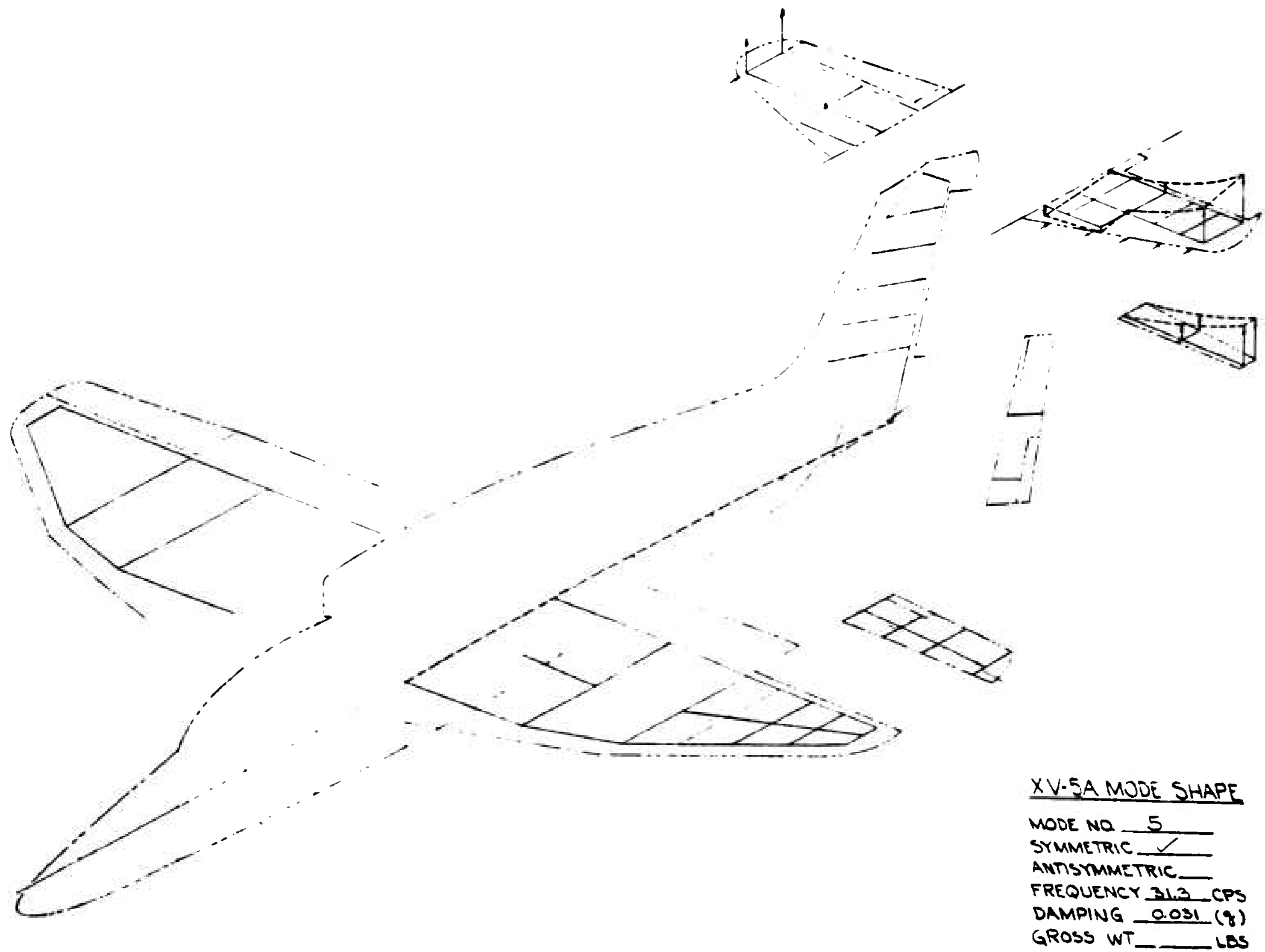


Figure 14 XV-5A Mode Shape - Mode No. 5

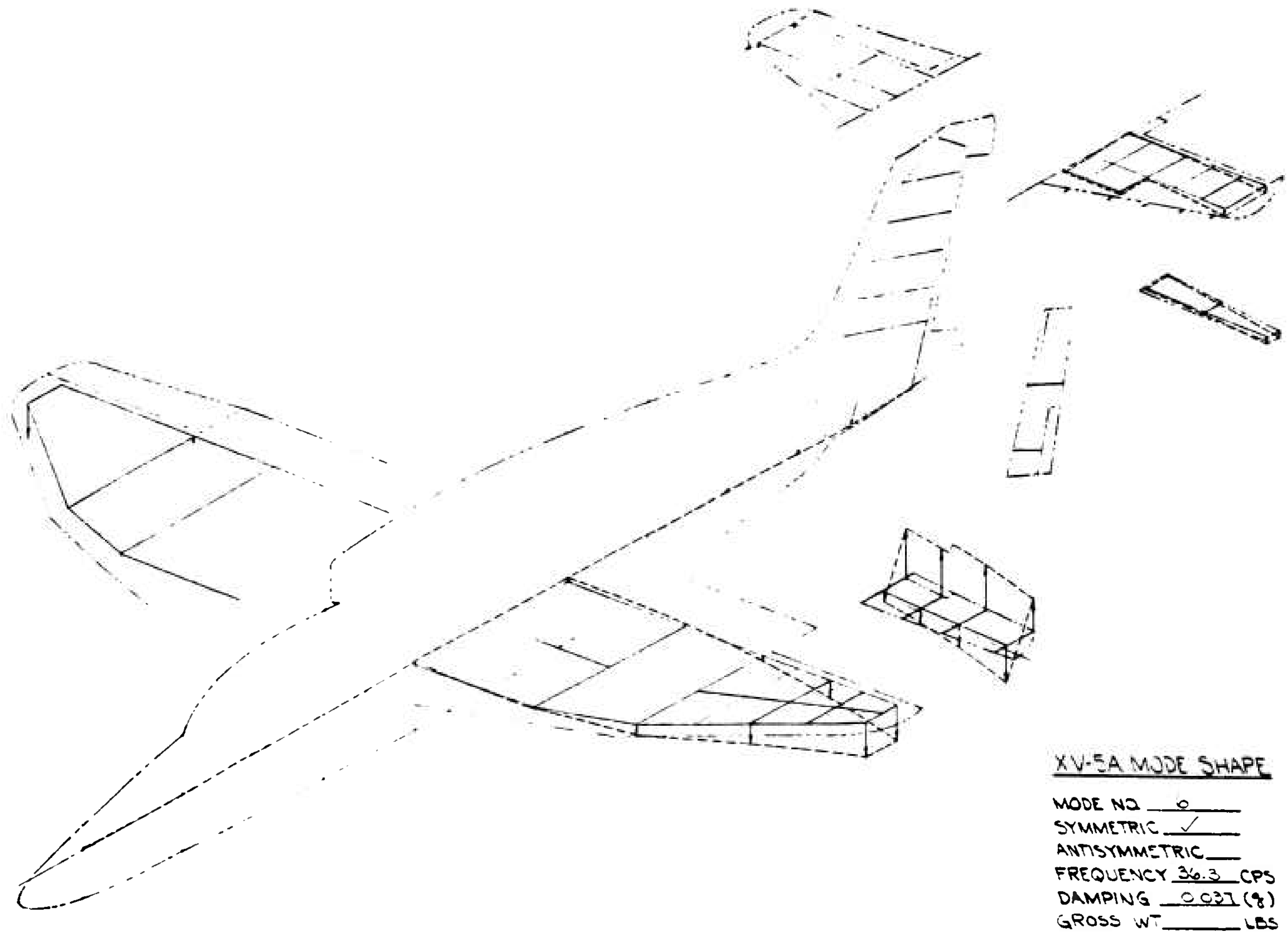


Figure 15 XV-5A Mode Shape - Mode No. 6

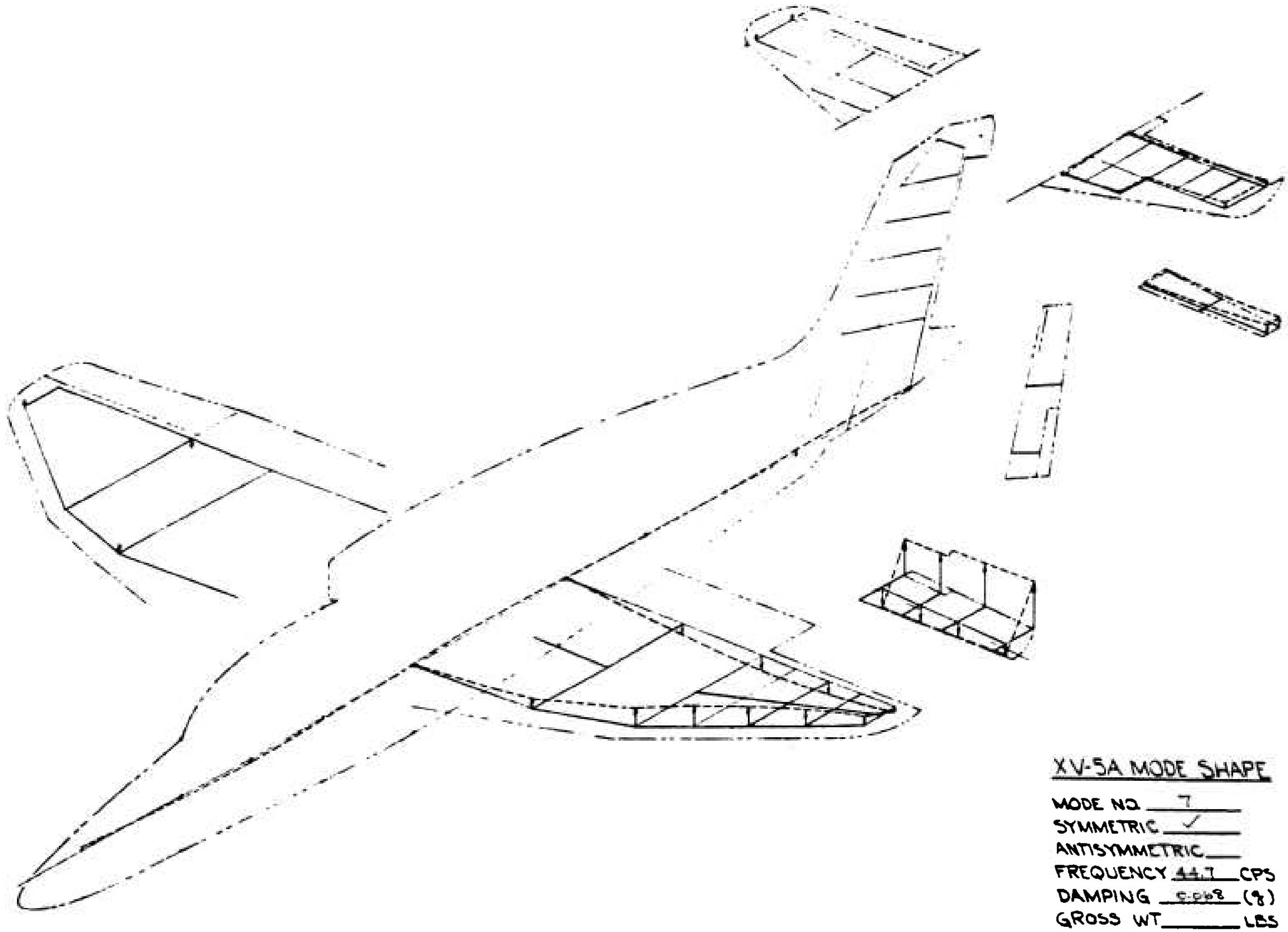


Figure 16 XV-5A Mode Shape - Mode No. 7

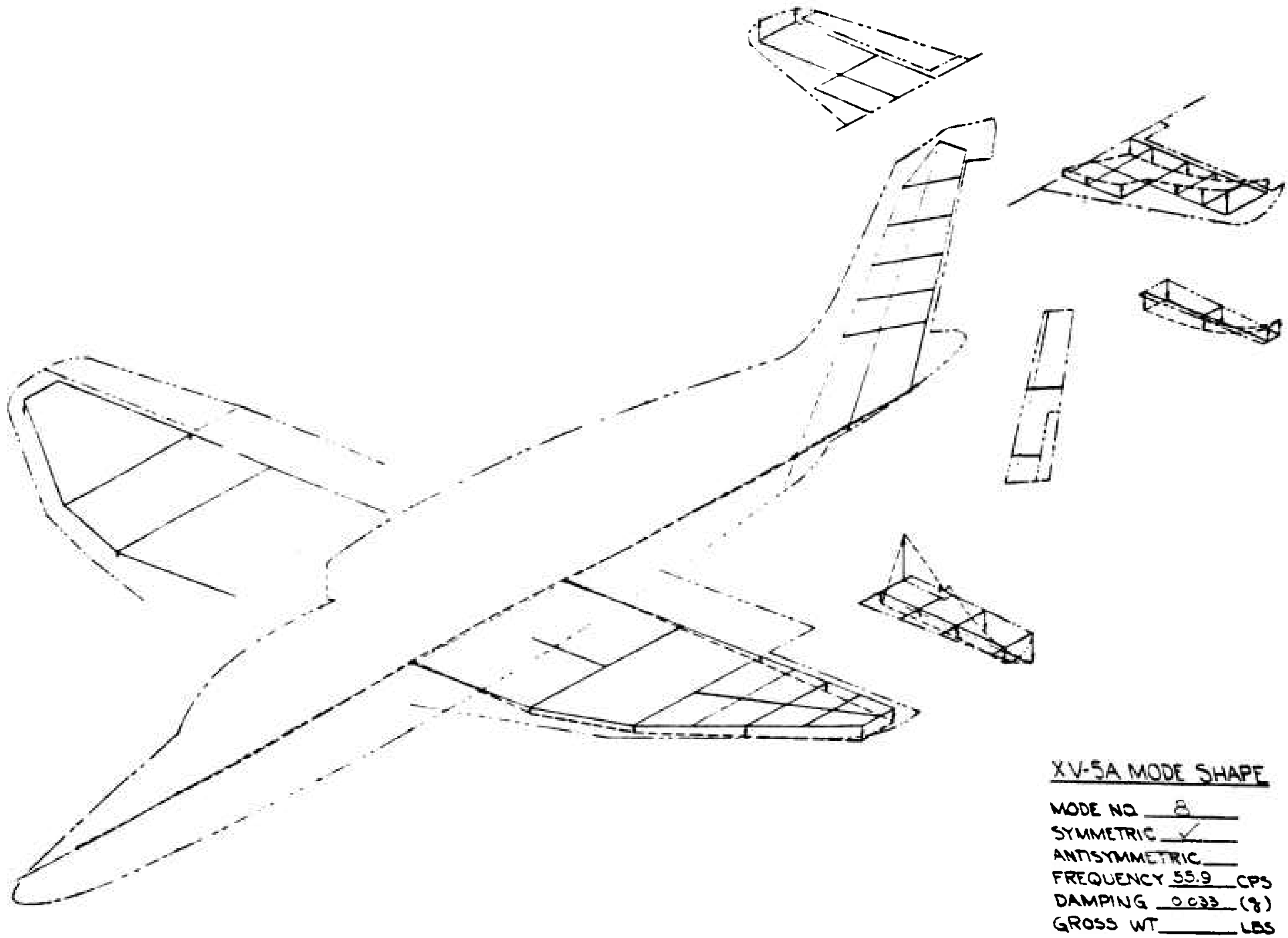


Figure 17 XV-5A Mode Shape - Mode No. 8

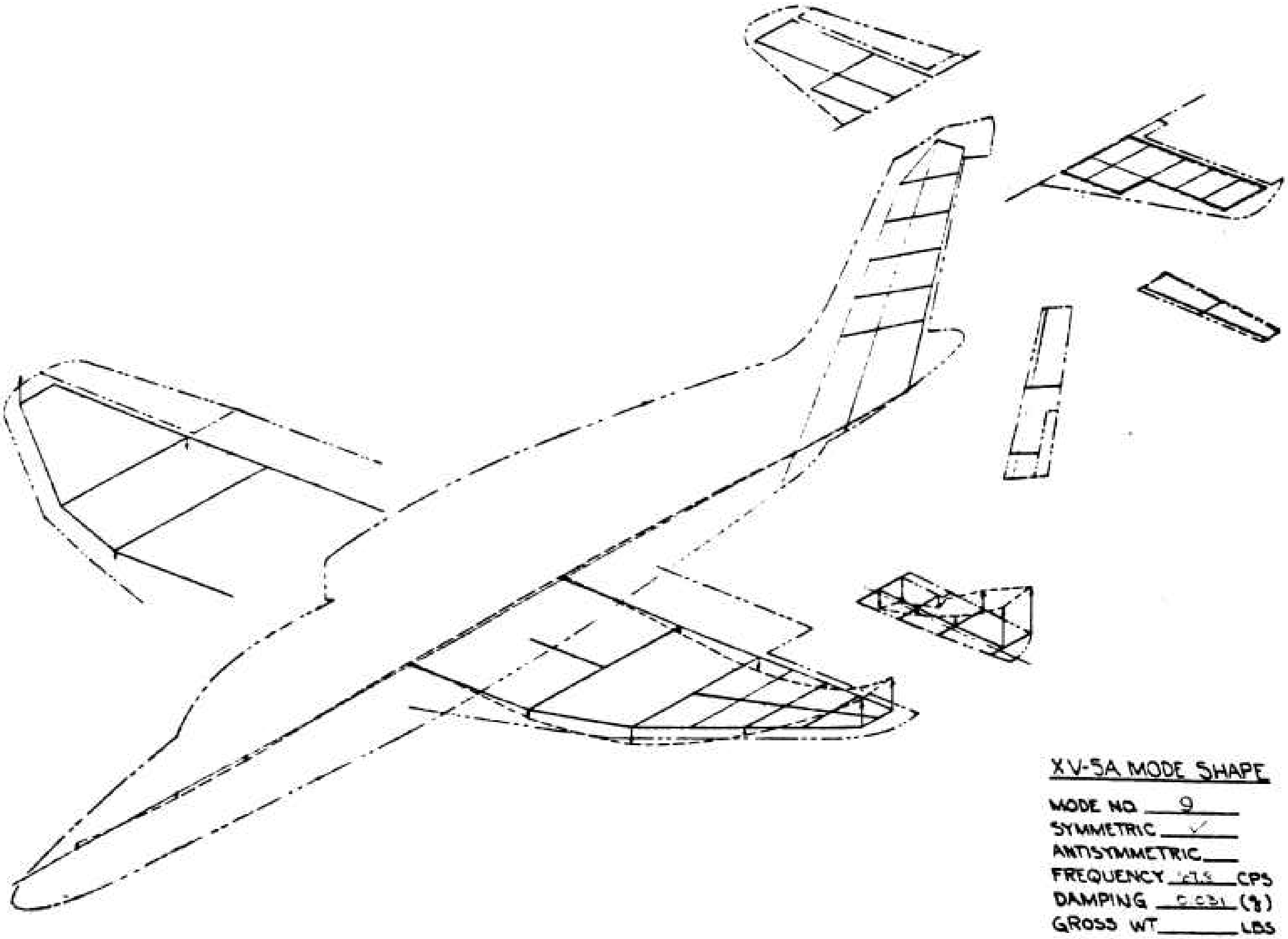


Figure 18 XV-5A Mode Shape - Mode No. 9

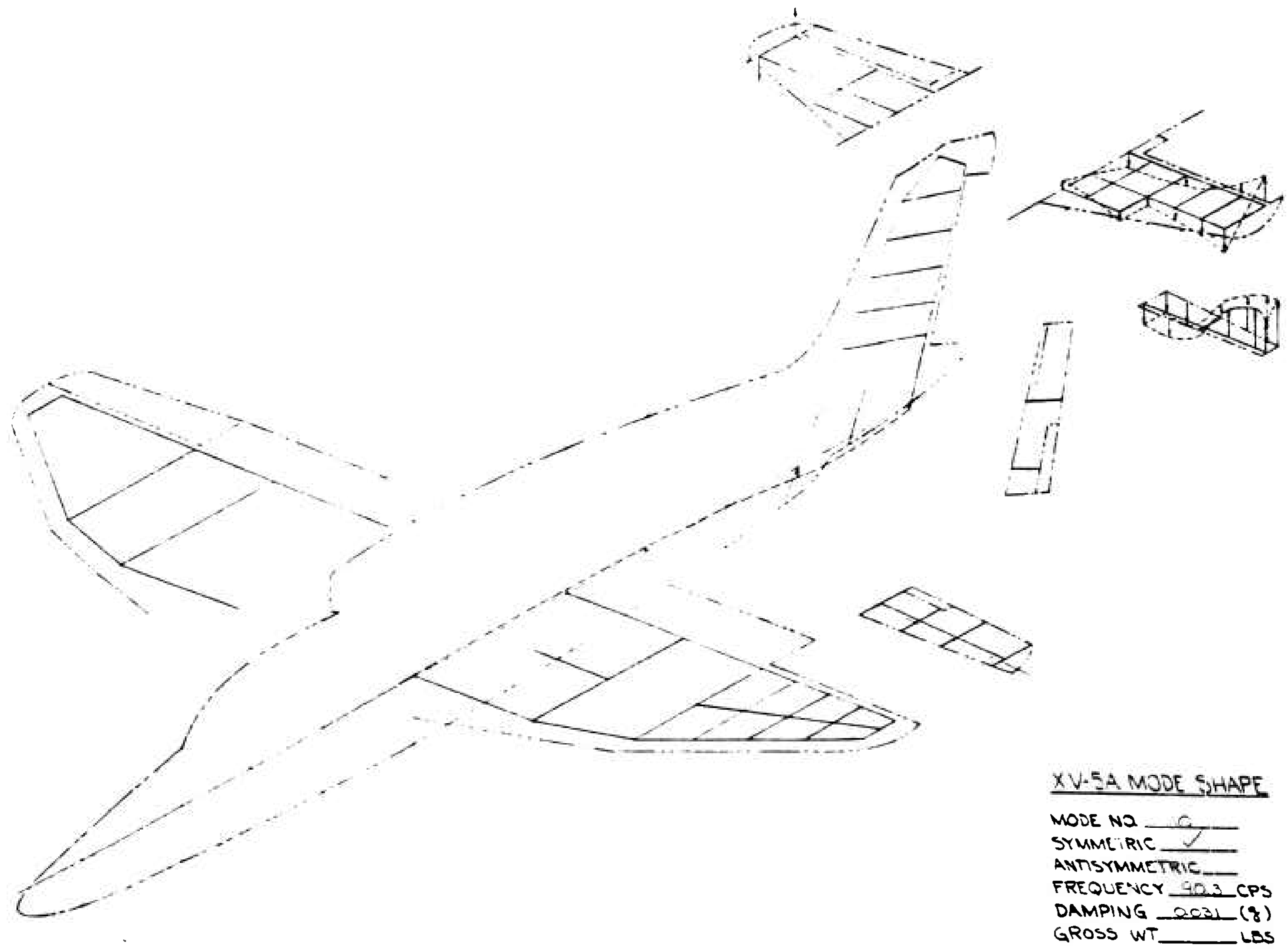


Figure 19 XV-5A Mode Shape - Mode No. 10

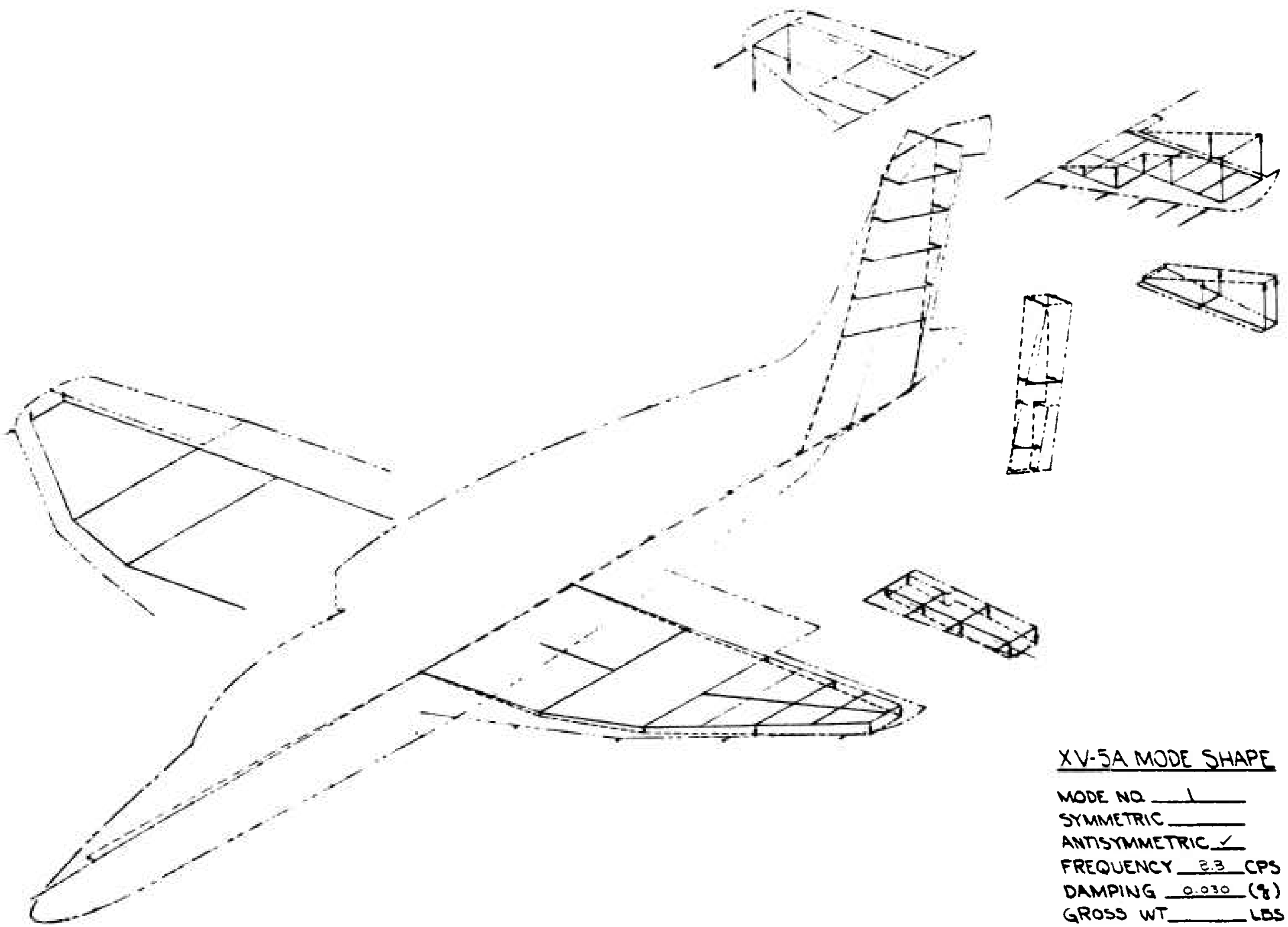


Figure 20 XV-5A Mode Shape - Mode No. 1

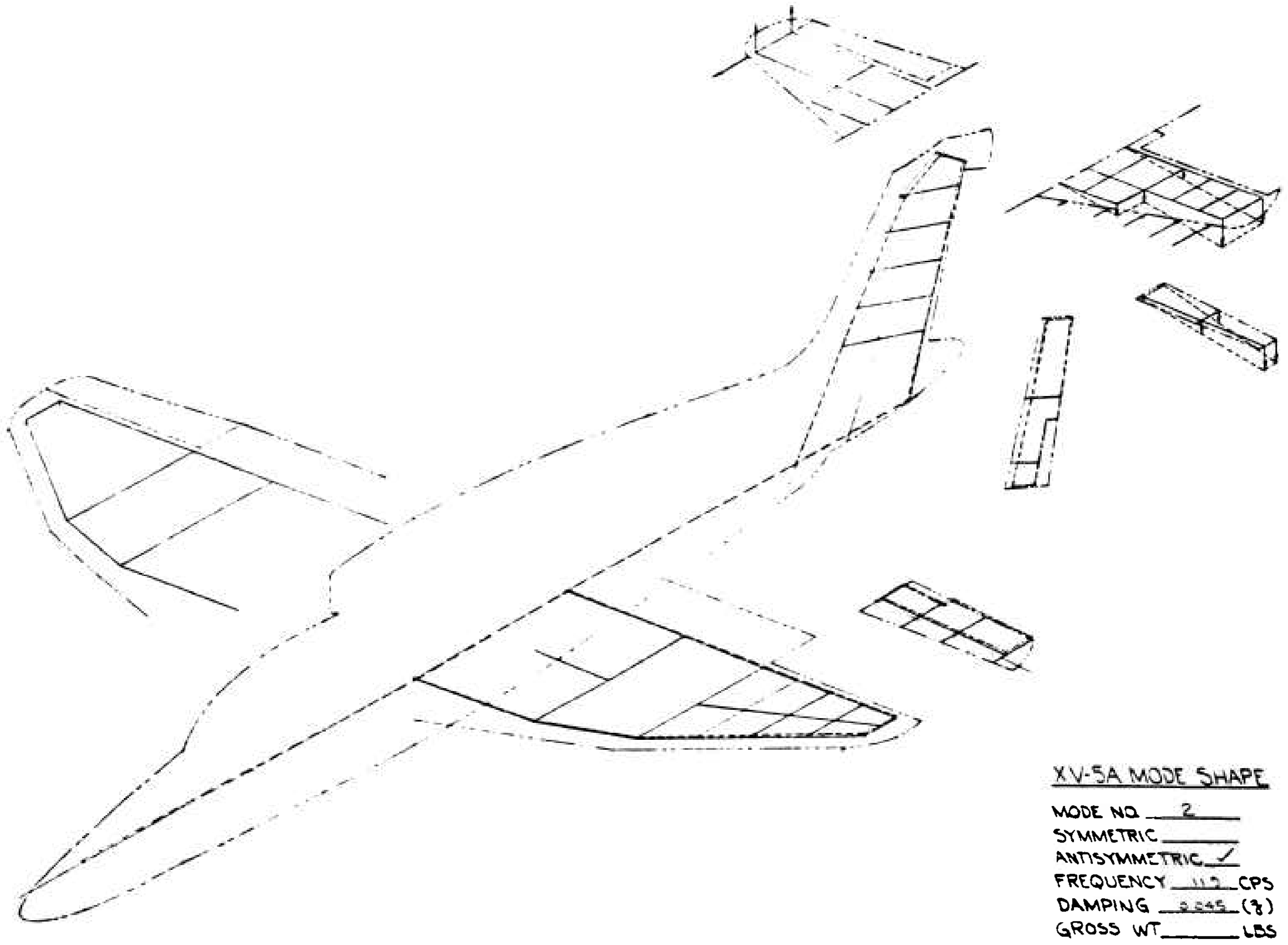


Figure 21 XV-5A Mode Shape - Mode No. 2

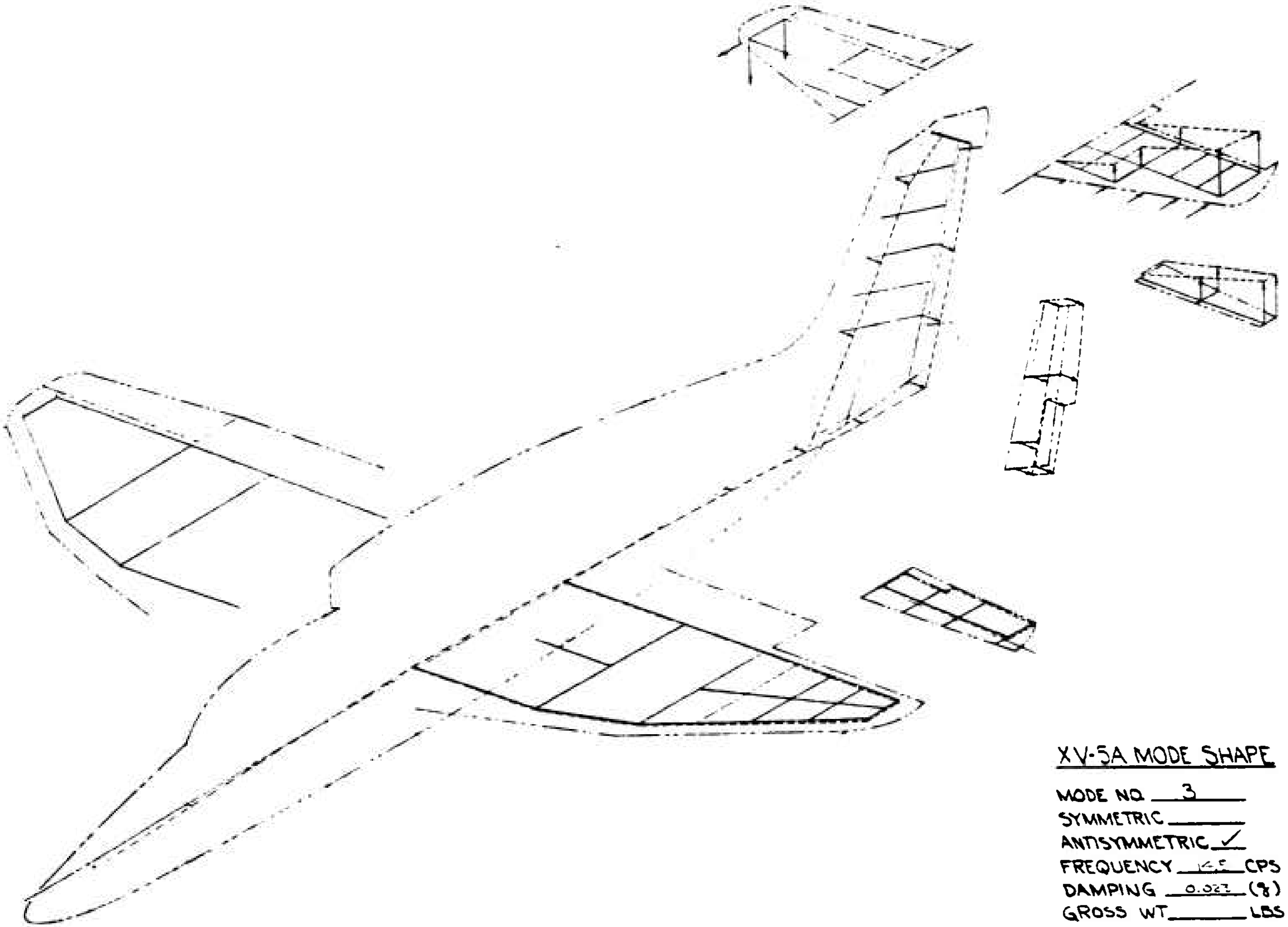


Figure 22 XV-5A Mode Shape - Mode No. 3

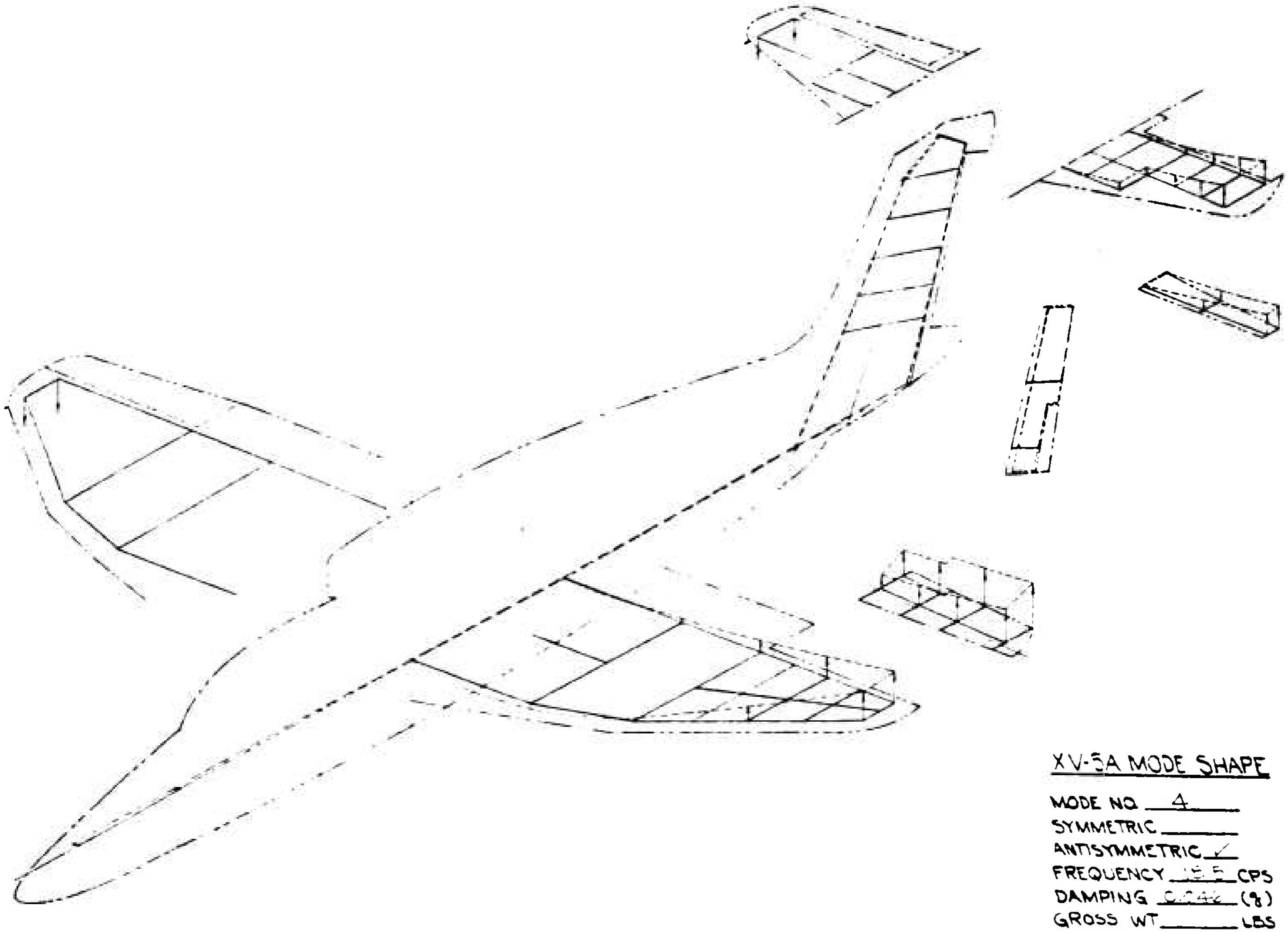


Figure 23   XV-5A Mode Shape - Mode No. 4

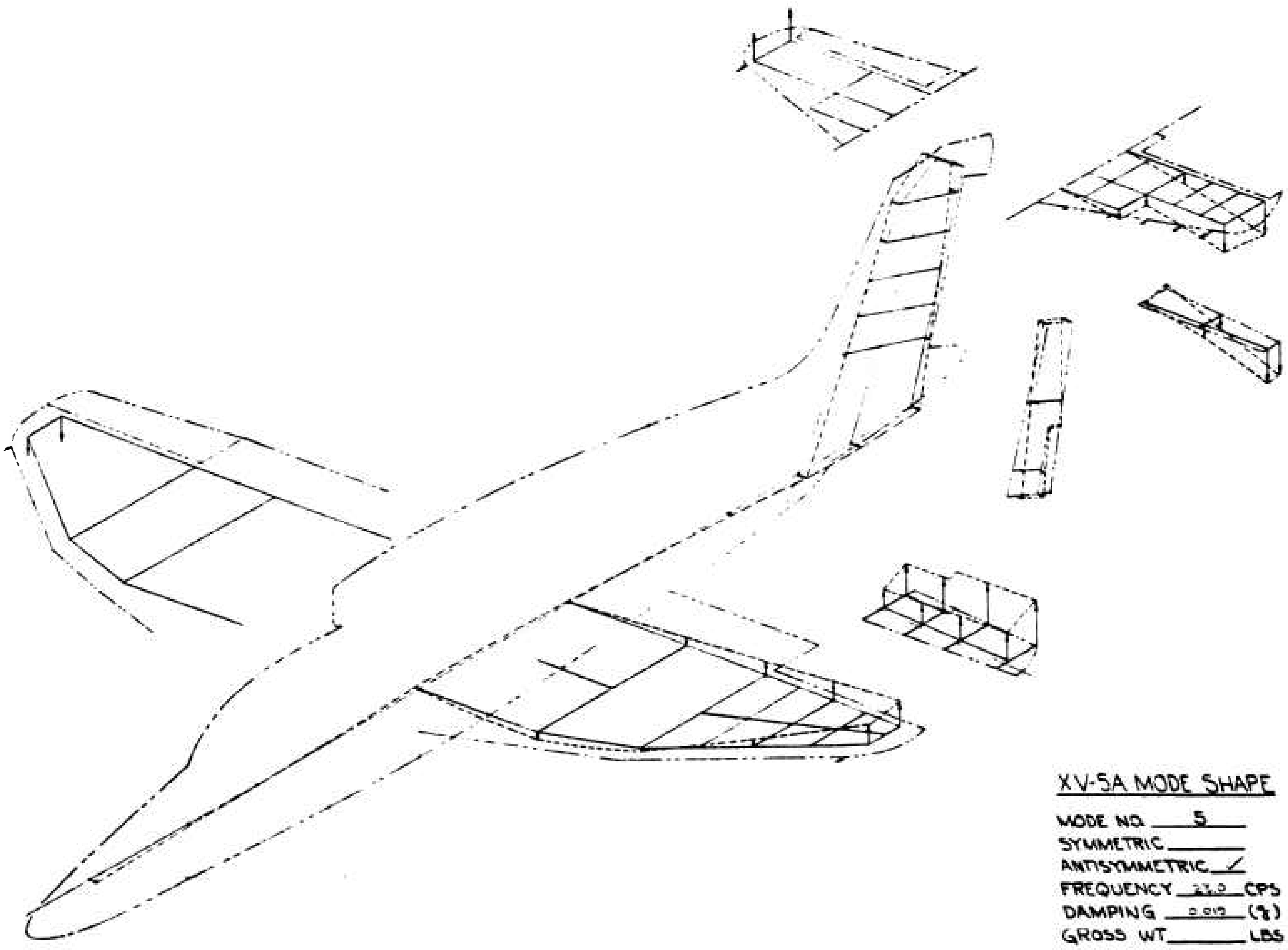


Figure 24 XV-5A Mode Shape - Mode No. 5

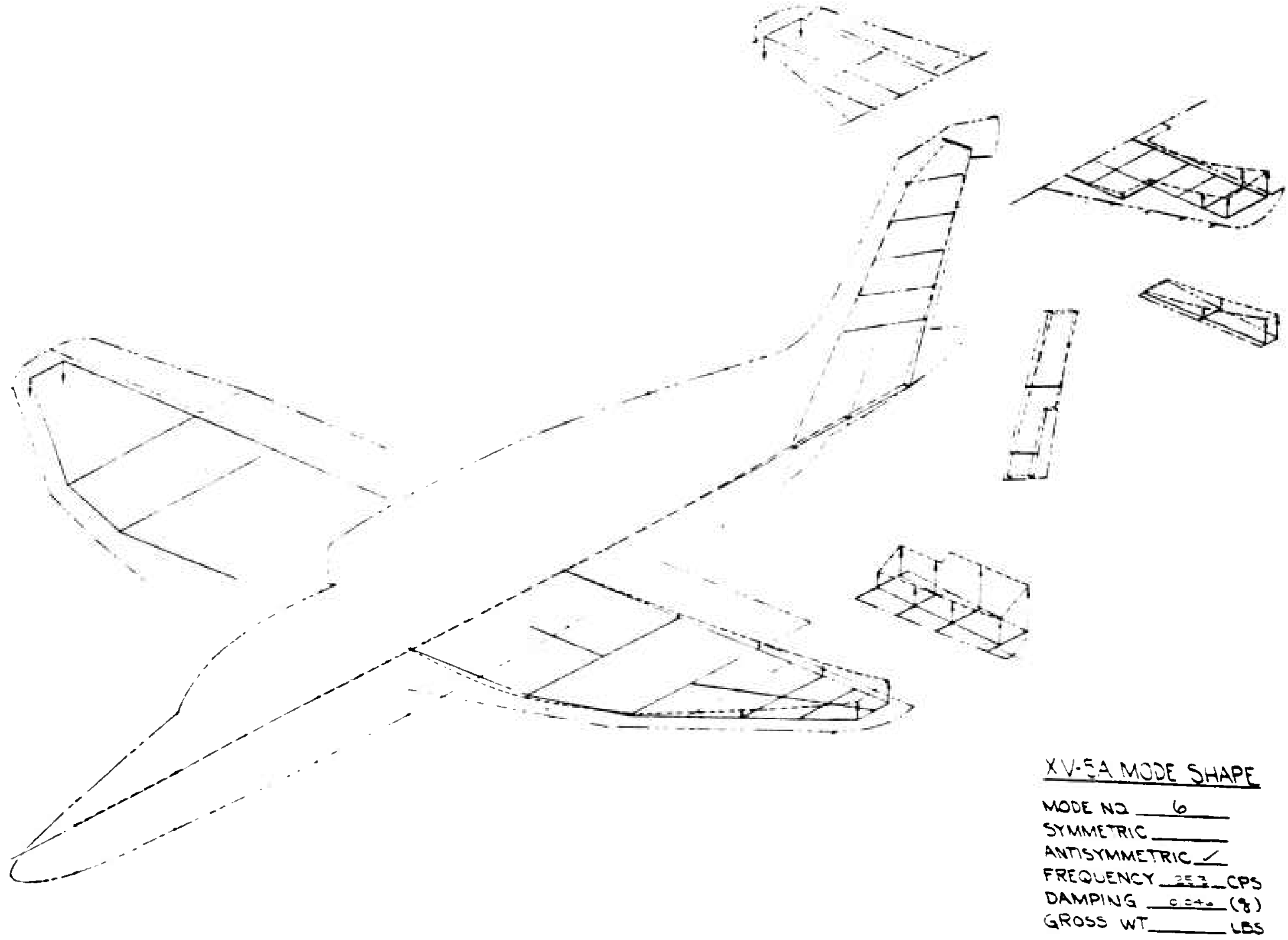


Figure 25 XV-5A Mode Shape - Mode No. 6

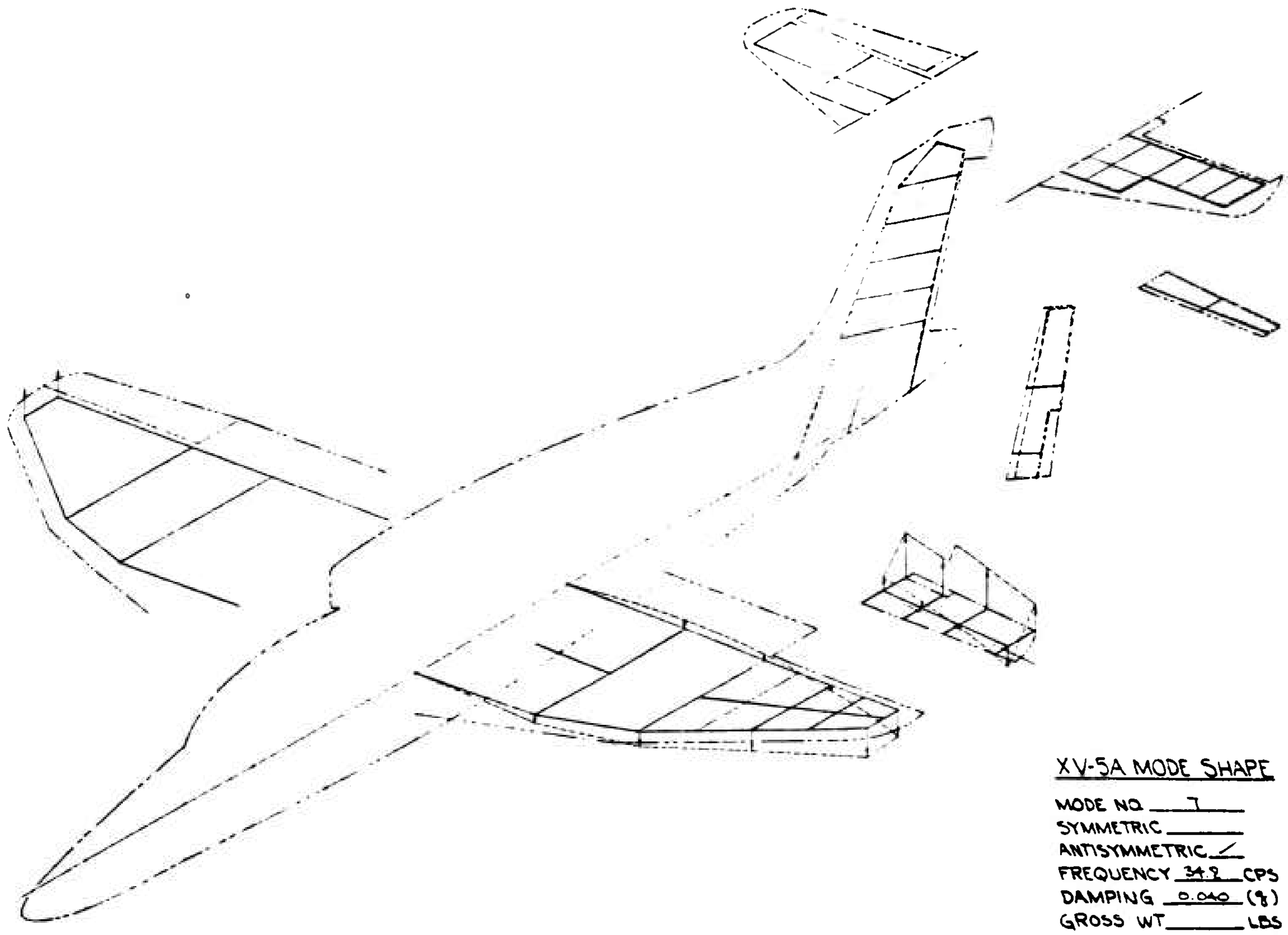


Figure 26 XV-5A Mode Shape - Mode No. 7

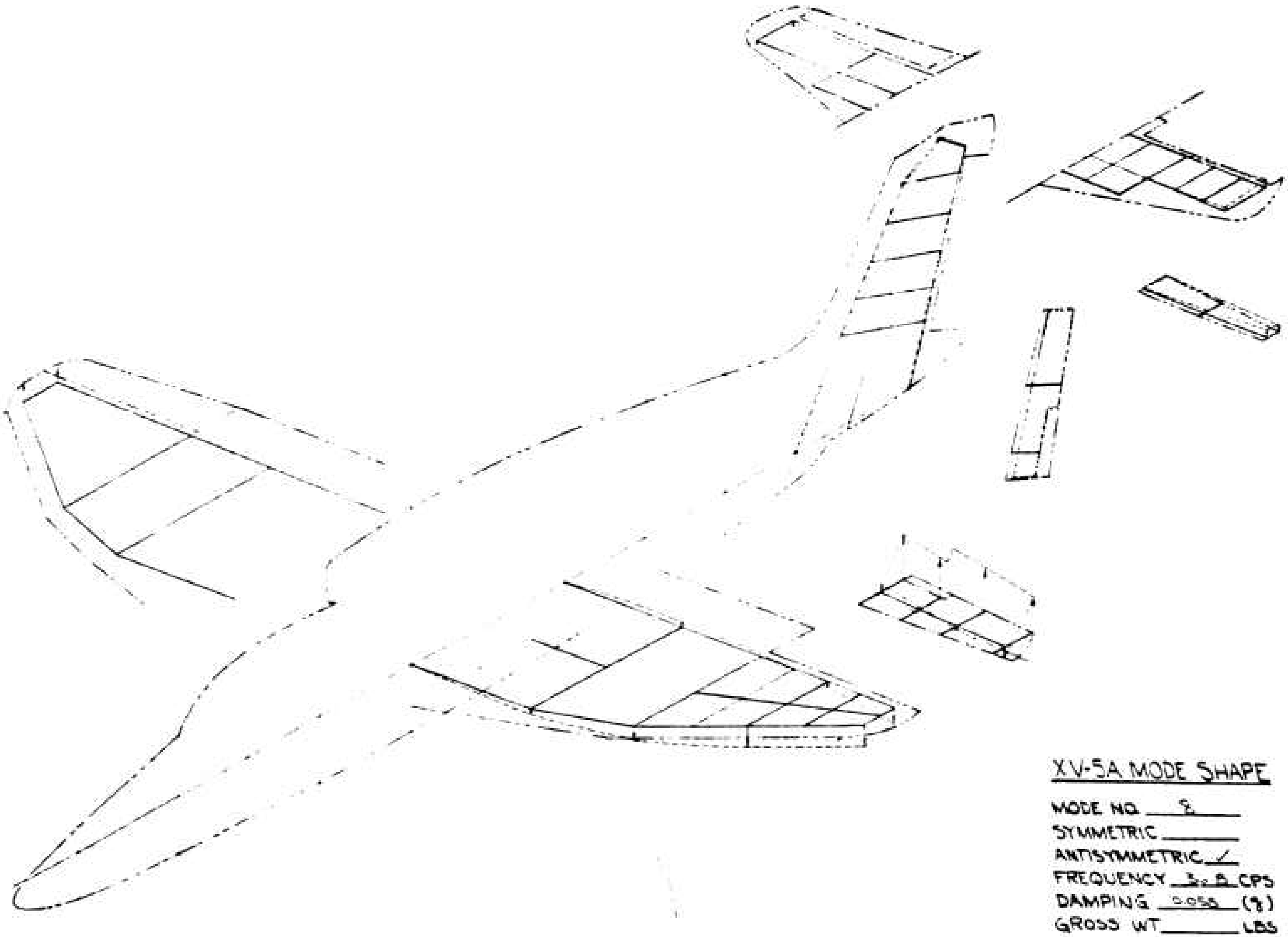


Figure 27 XV-5A Mode Shape - Mode No. 8

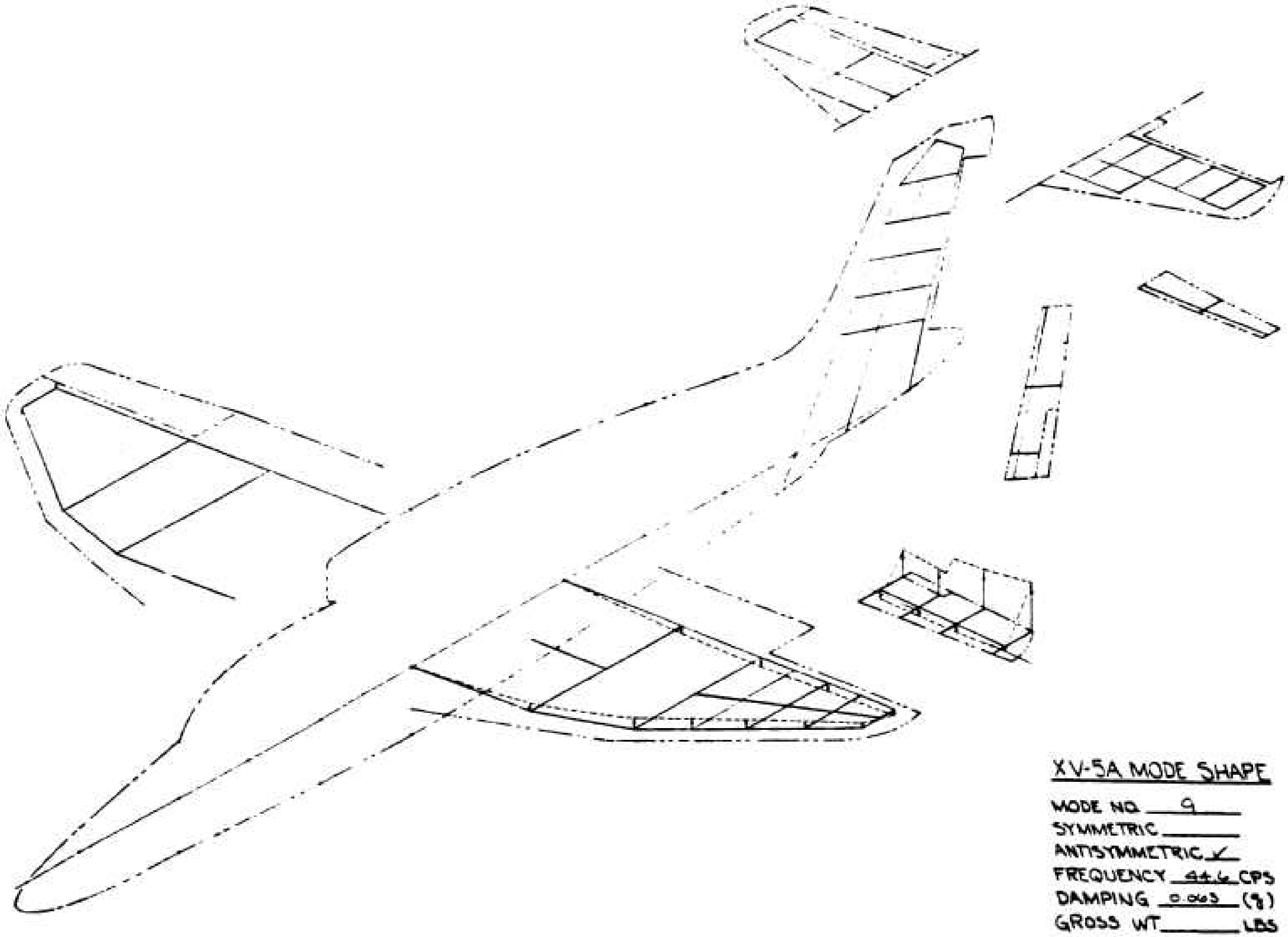


Figure 28 XV-5A Mode Shape - Mode No. 9

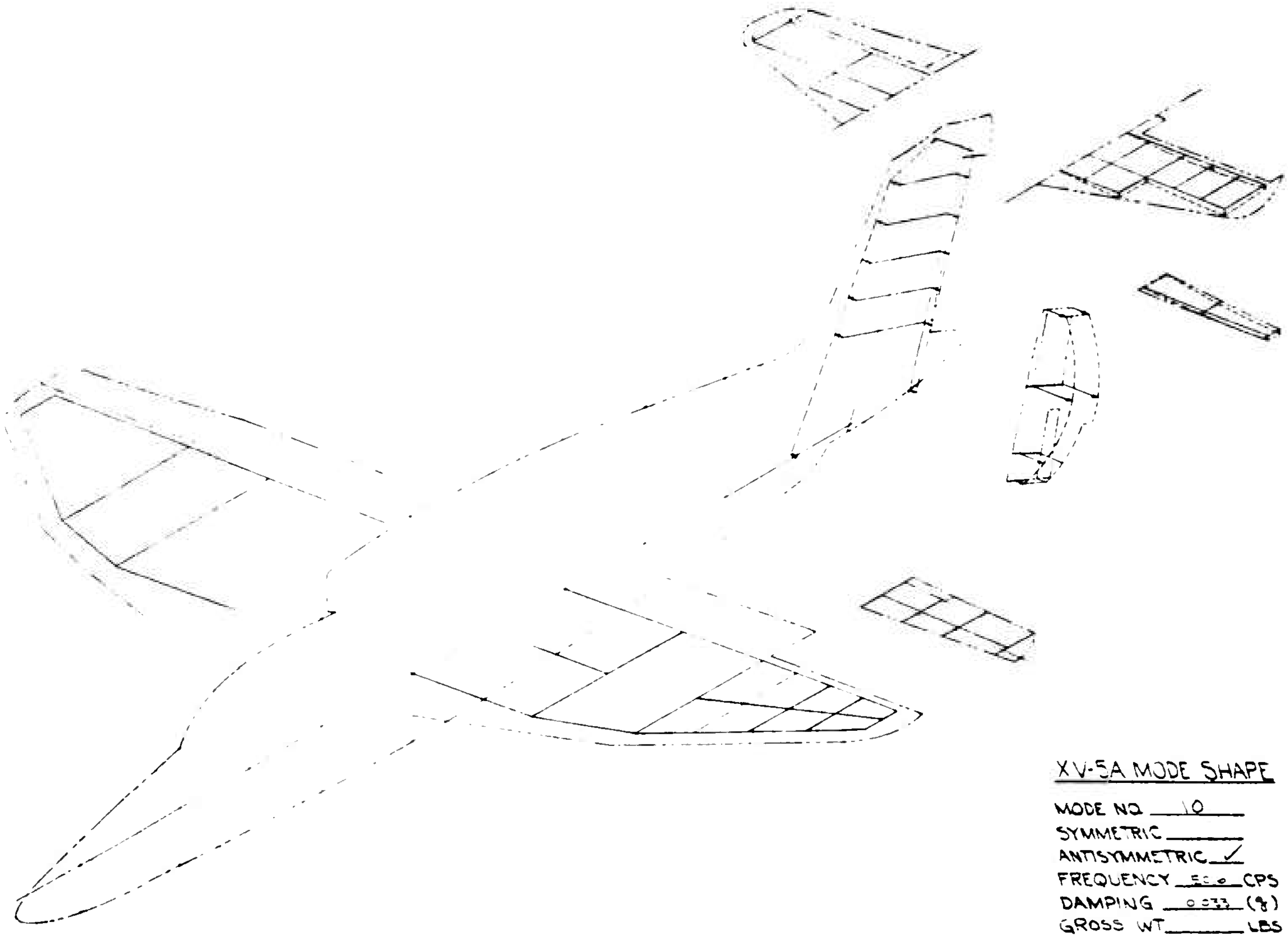


Figure 29 XV-5A Mode Shape - Mode No. 10

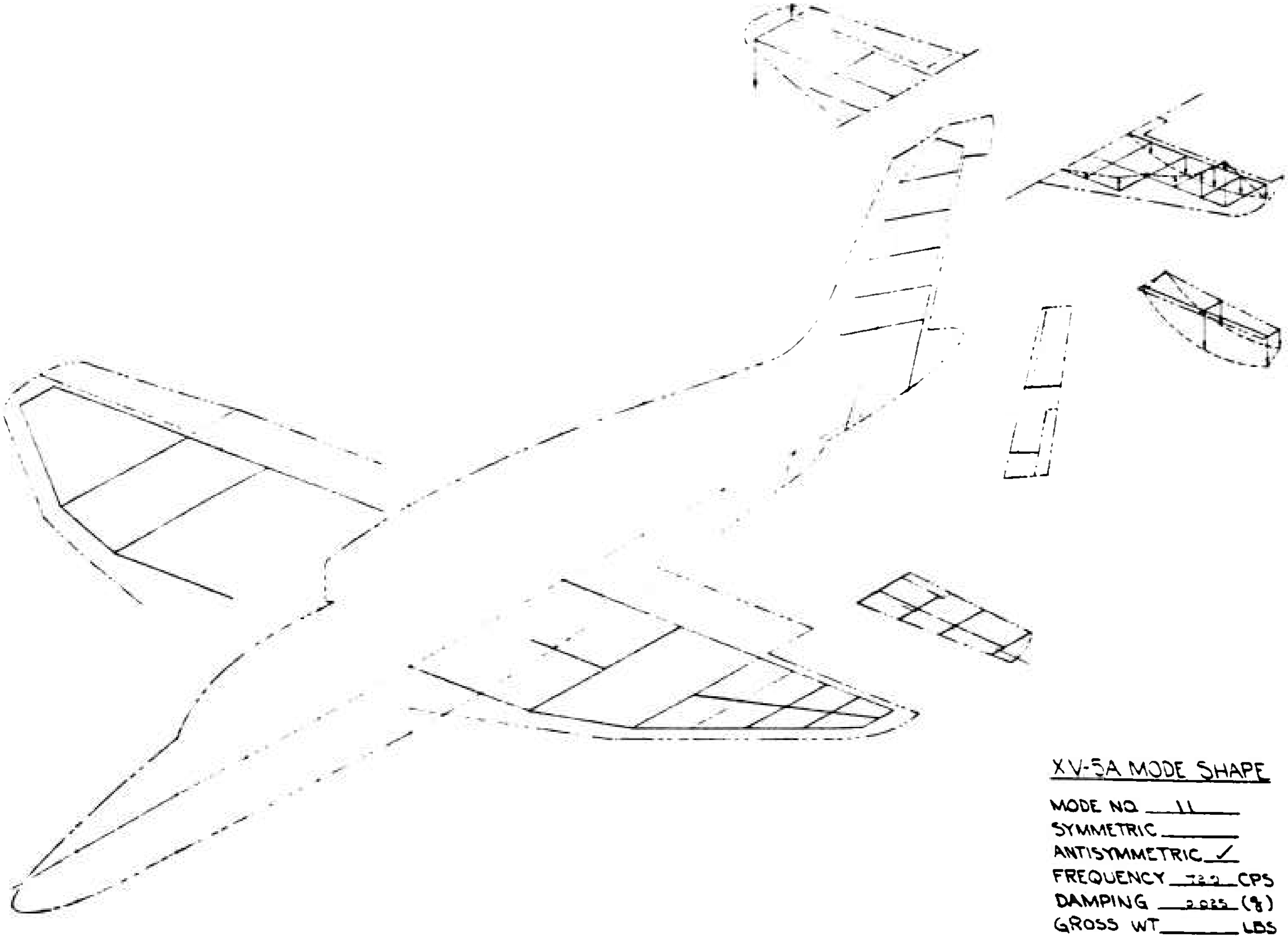


Figure 30   XV-5A Mode Shape - Mode No. 11

REF: DWG 143W010

POINT	STA.	WL	BL
INBD HINGE	308.15	92.58	24.62
OUTBD "	308.15	92.58	100.75
ACTUATOR	307.50	100.58	21.94

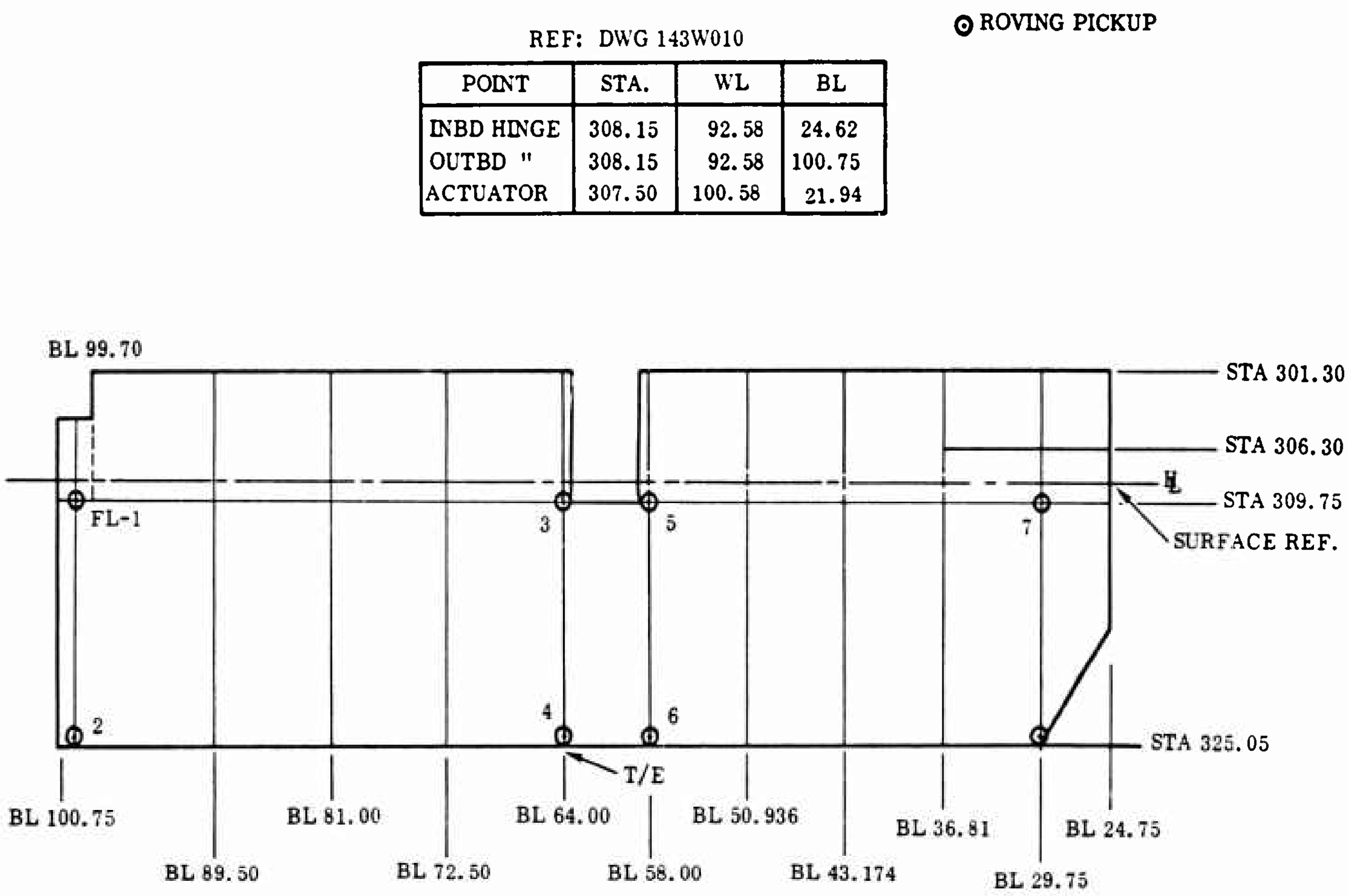


Figure 31 Miscellaneous Component Pickup Locations - Flap

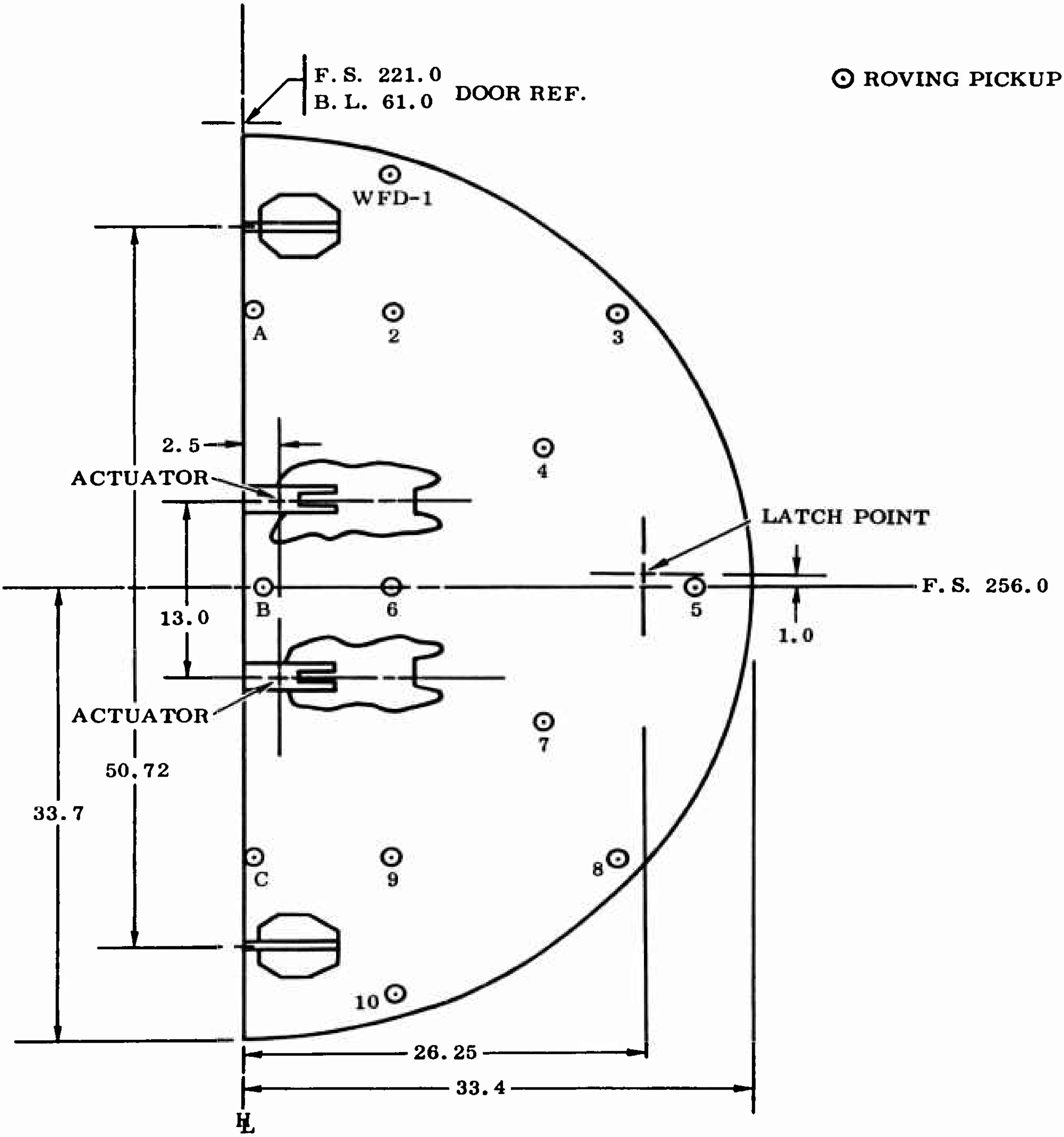


Figure 32 Miscellaneous Component Pickup Locations - Wing Fan Door

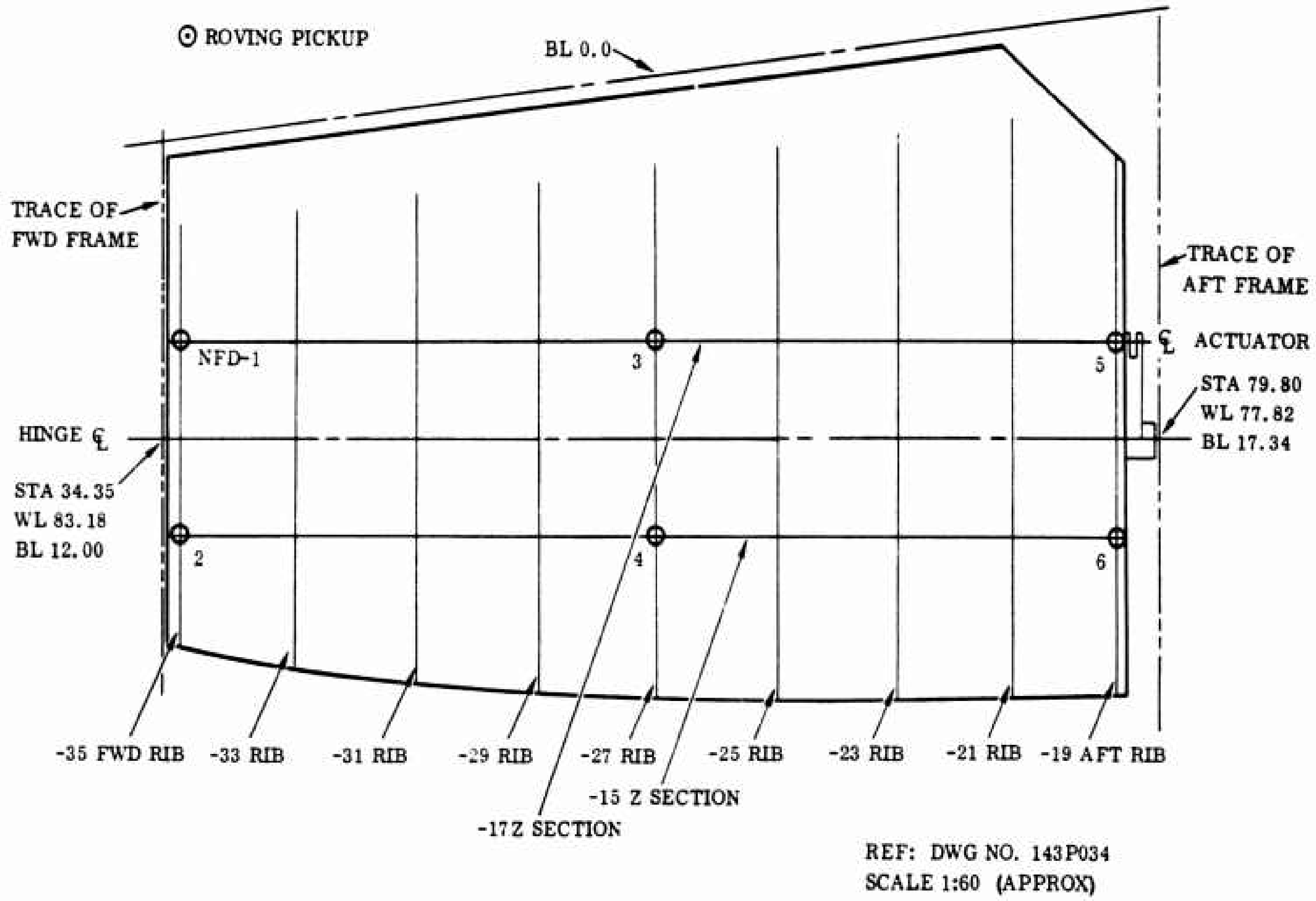


Figure 33 Miscellanous Component Pickup Locations - Nose Fan Door

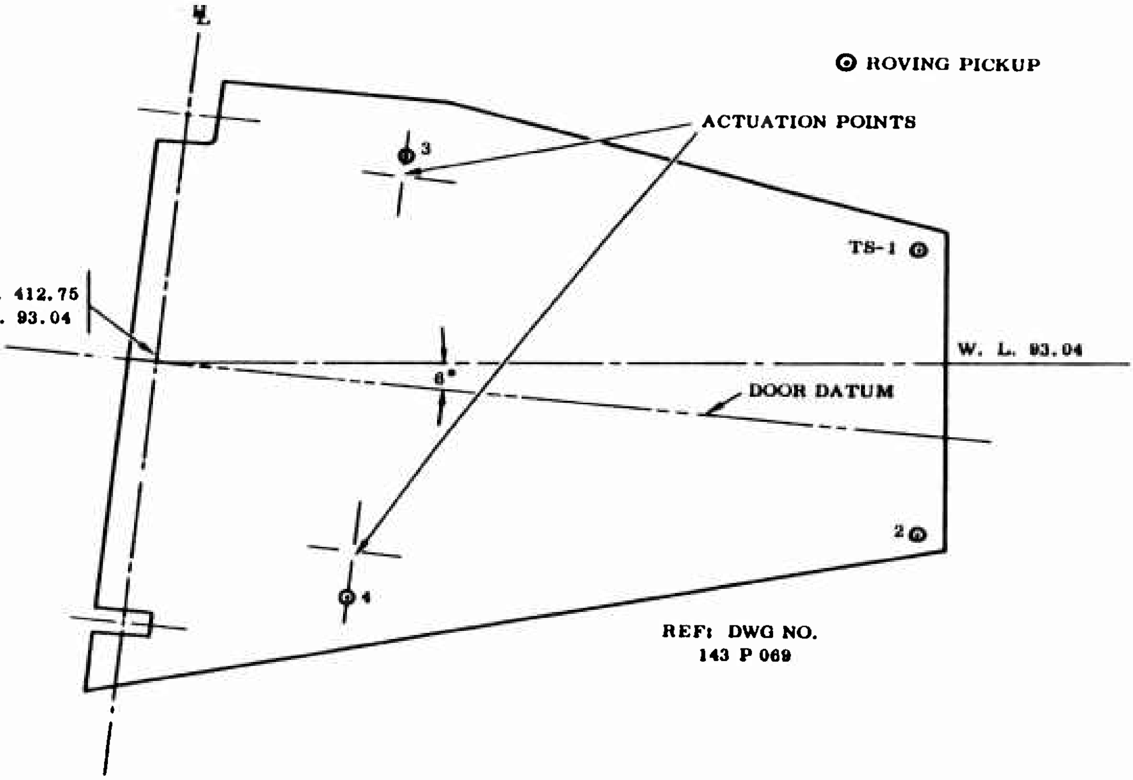
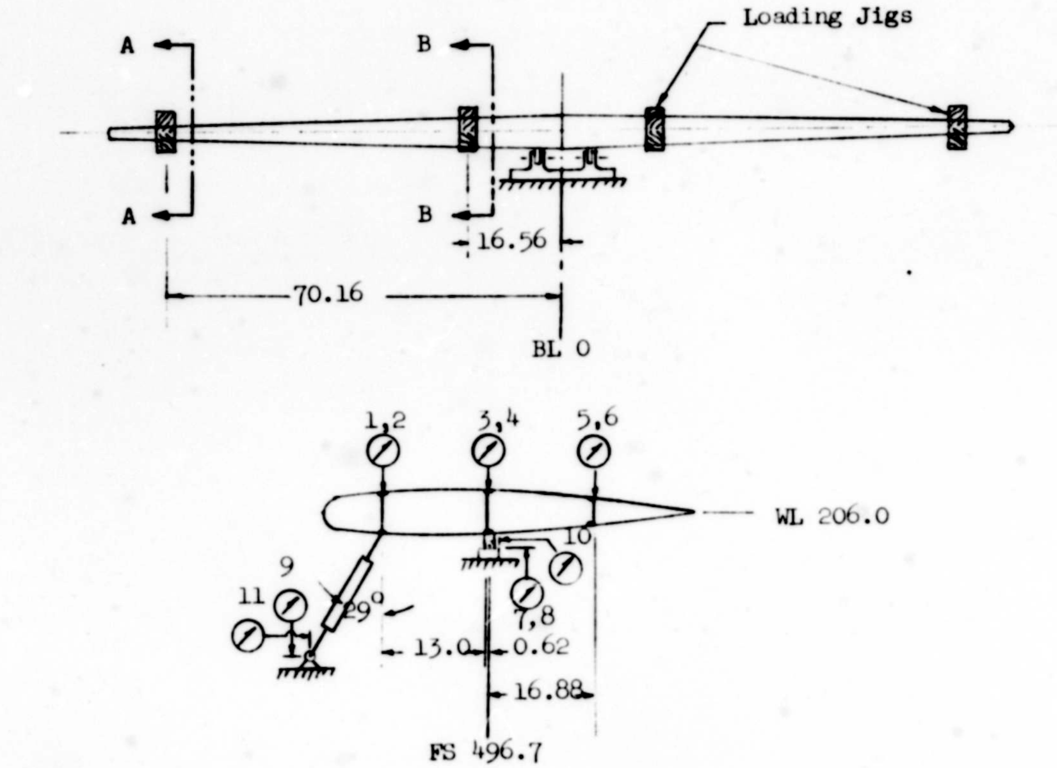
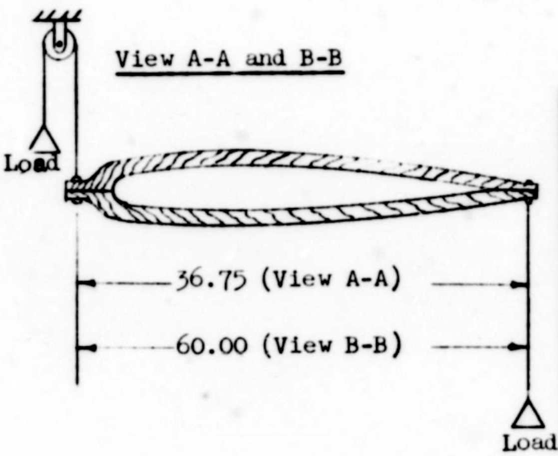


Figure 34 Miscellaneous Component Pickup Locations - Thrust Spoiler





Defl. Gage	Location	Sense
1	Fwd.Spar-BL 3.26 (Left)	Vert.
2	Fwd.Spar-BL 3.26 (Right)	Vert.
3	Ctr.Spar BL 3.26 (Left)	Vert.
4	Ctr.Spar BL 3.26 (Right)	Vert.
5	Aft Spar BL 3.26 (Left)	Vert.
6	Aft Spar BL 3.26 (Right)	Vert.
7	Pivot Ftg. BL 5.0 (Left)	Vert.
8	Pivot Ftg. BL 5.0 (Right)	Vert.
9	Actuator Support BL 0	Vert.
10	Pivot Support BL 0	F & A
11	Actuator Support BL 0	F & A

Vert - Vertical
F&A - Fore and Aft

Figure 35. Horizontal Stabilizer Pitch Spring - Load and Instrumentation Schematic

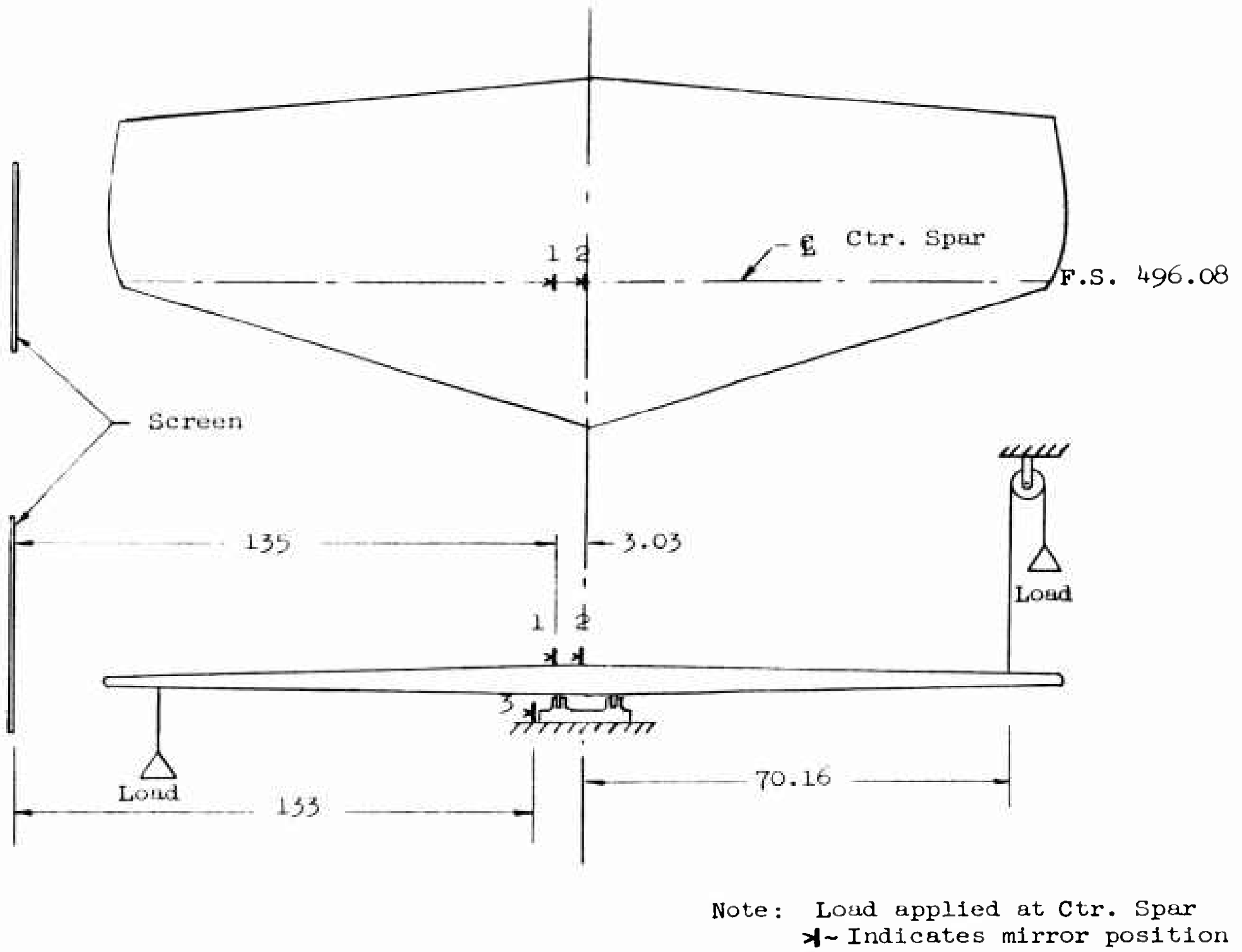


Figure 36. Horizontal Stabilizer Roll Spring - Load and Instrumentation Schematic

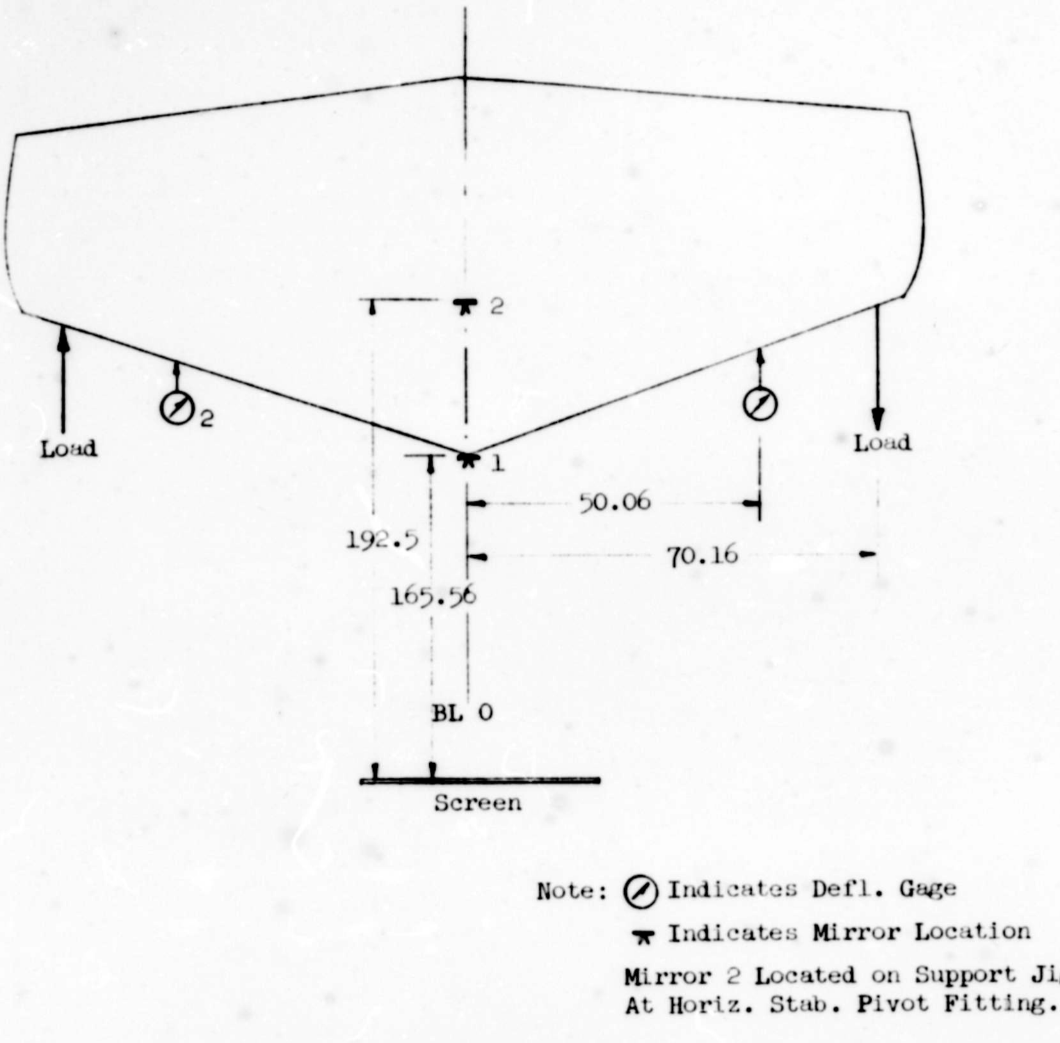


Figure 37. Horizontal Stabilizer Yaw Spring - Load and Instrumentation Schematic

Figure 38. Test Setup - Horizontal Stabilizer Pitch Restraint

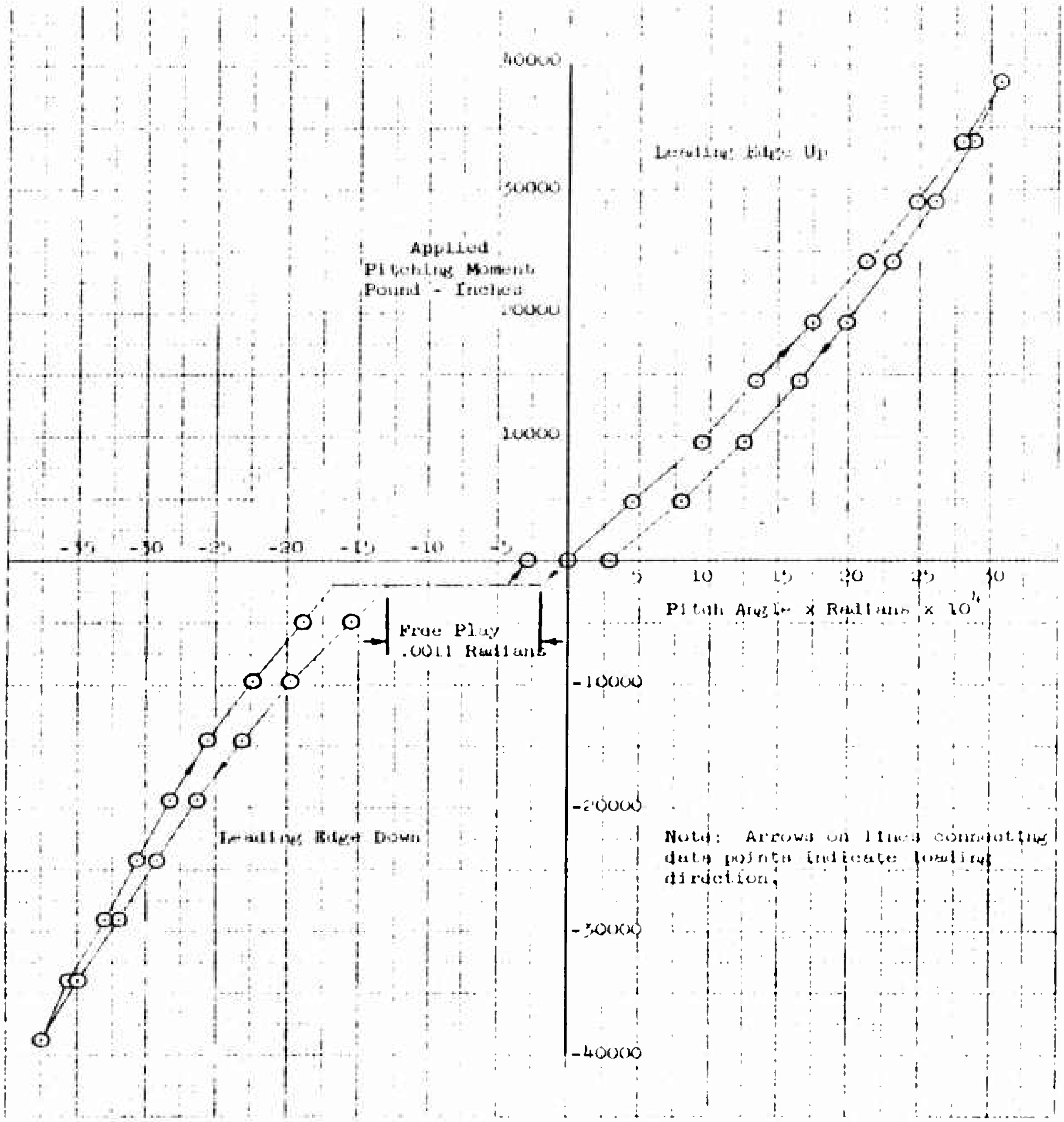


Figure 39. Horizontal Stabilizer - Pitch Free Play and Rotational Restraint

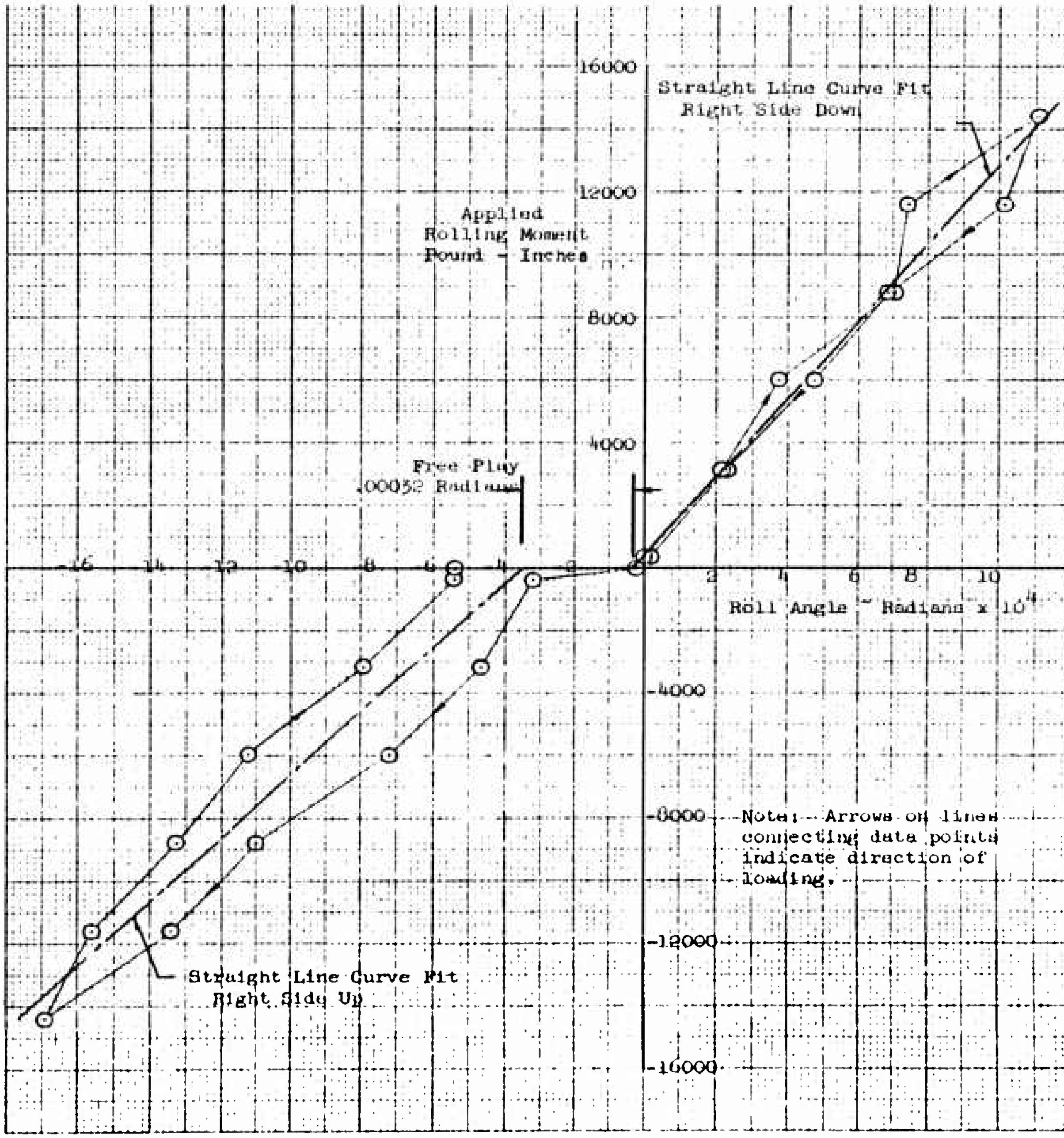


Figure 40. Horizontal Stabilizer - Roll Free Play and Rotational Restraint

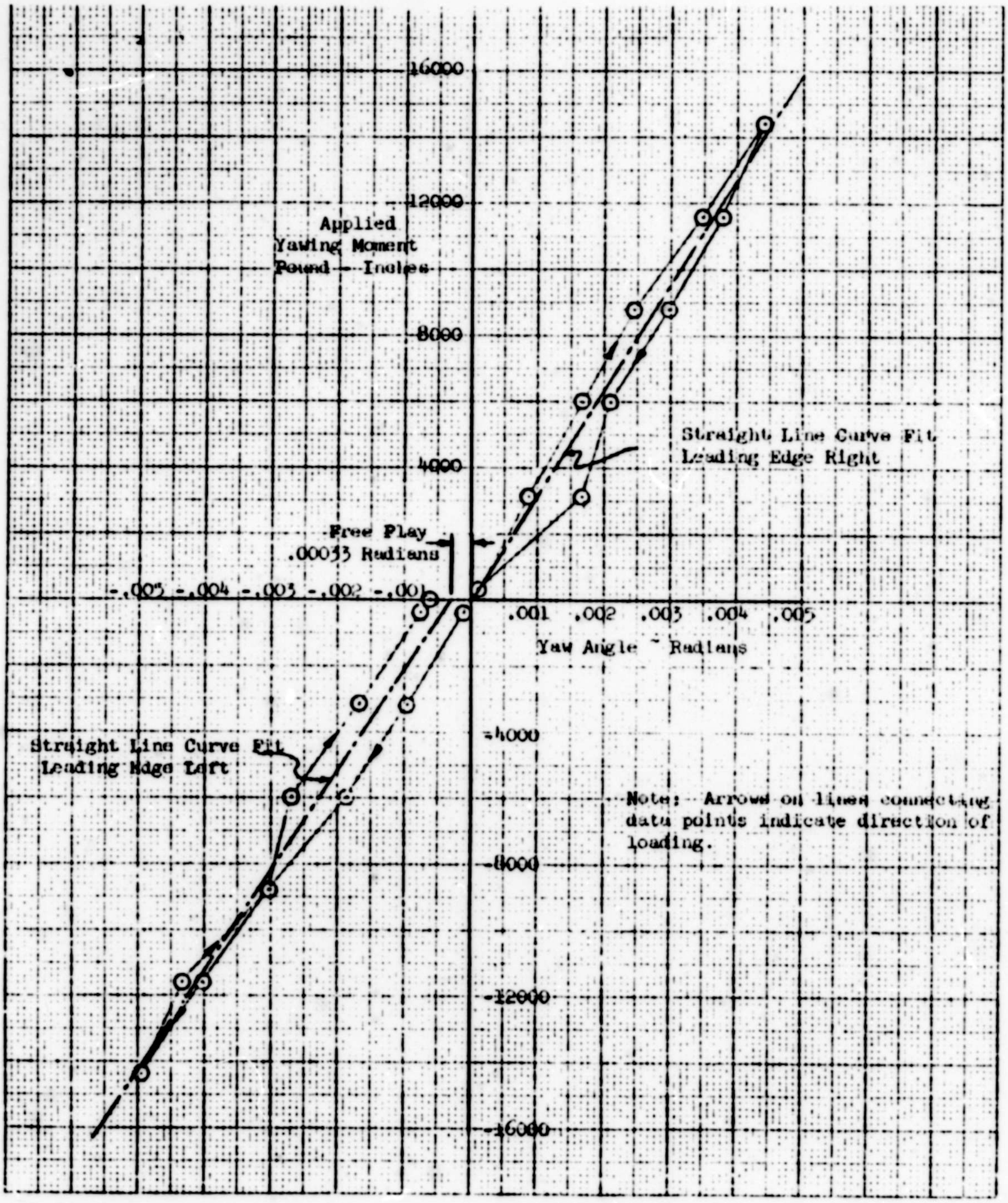


Figure 41. Horizontal Stabilizer - Yaw Free Play and Rotational Restraint

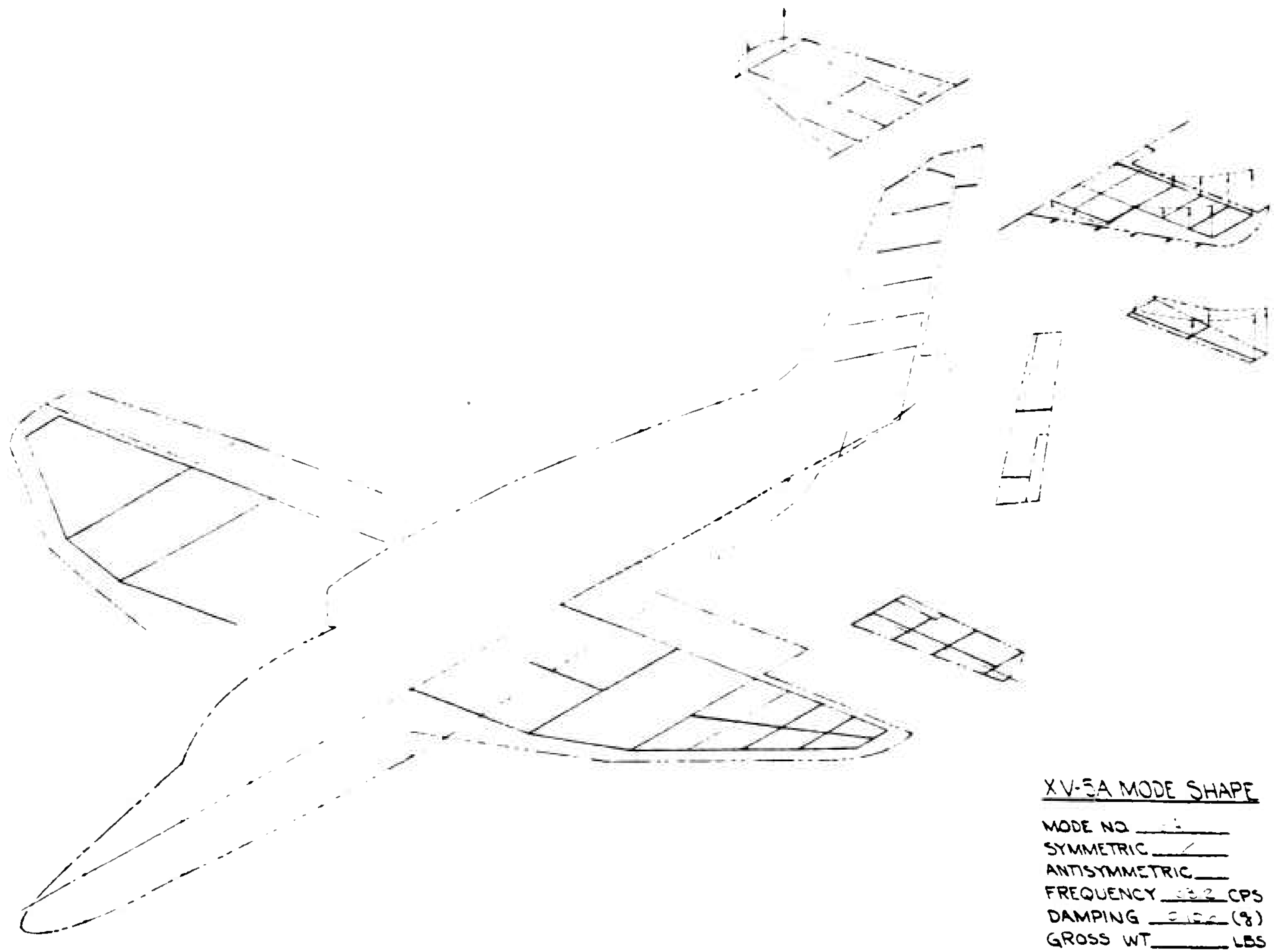


Figure 42 XV-5A Mode Shape - Mode No. 5A

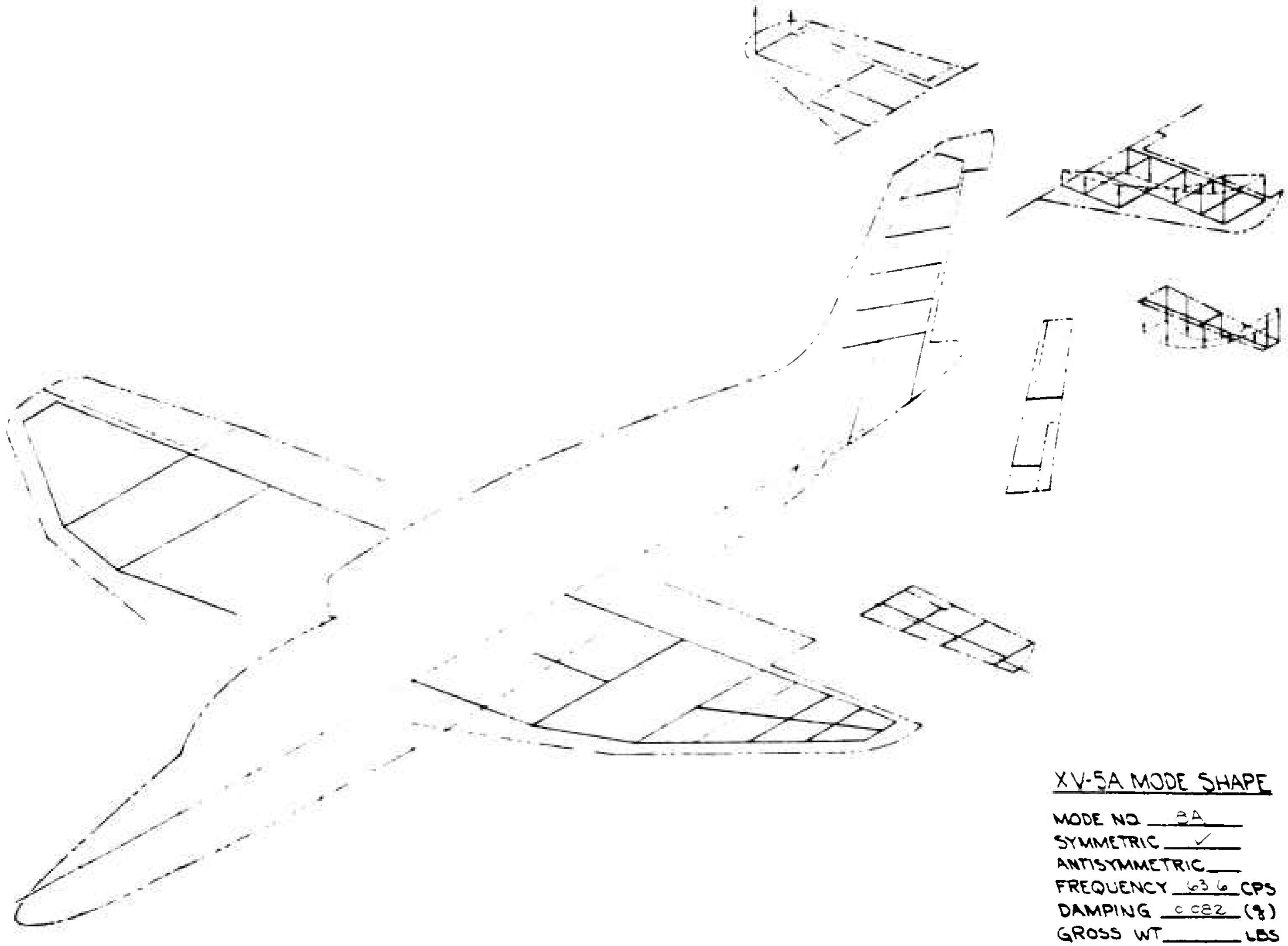


Figure 43 XV-5A Mode Shape - Mode No. 8A

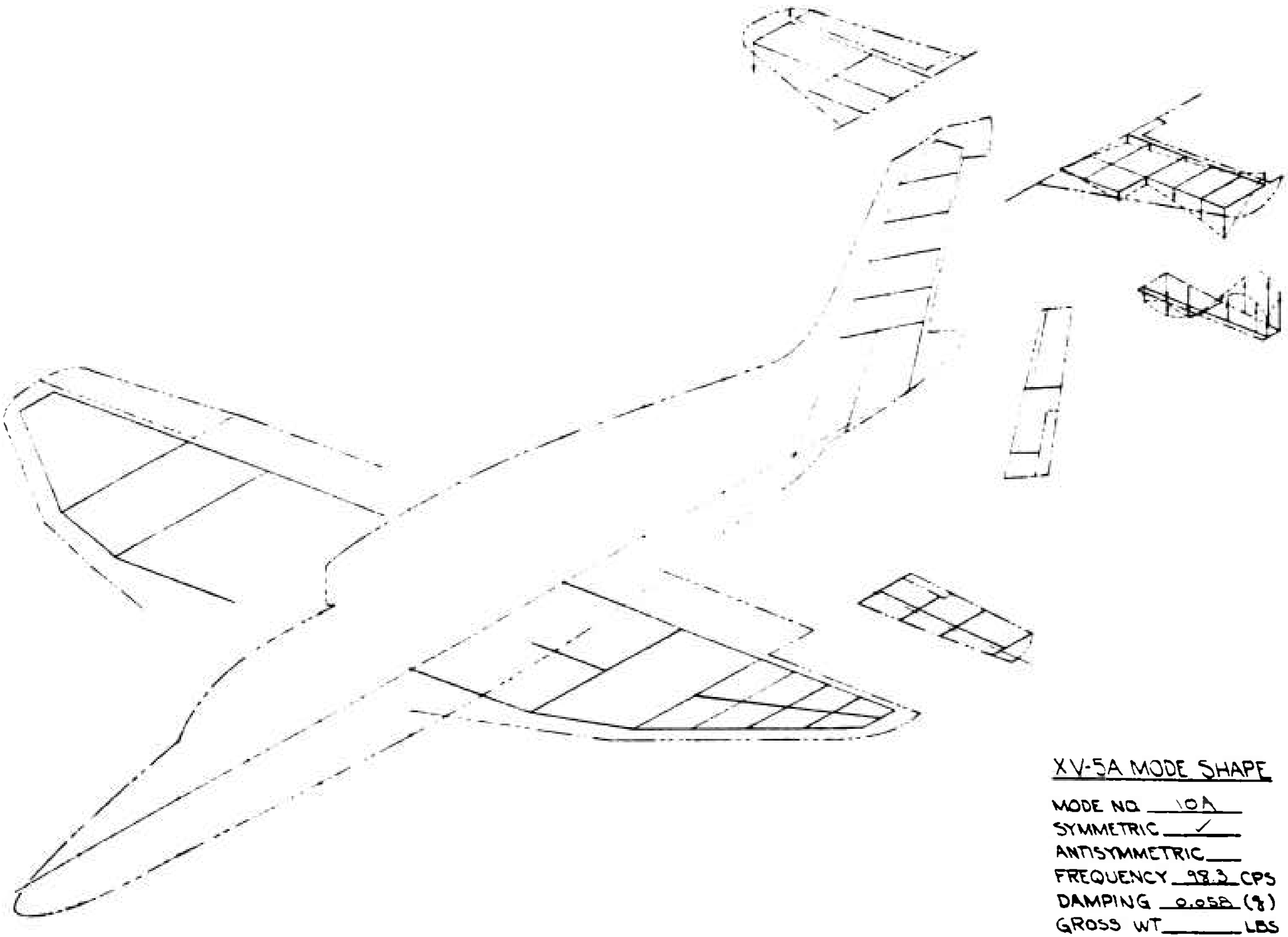


Figure 44 XV-5A Mode Shape - Mode No. 10A

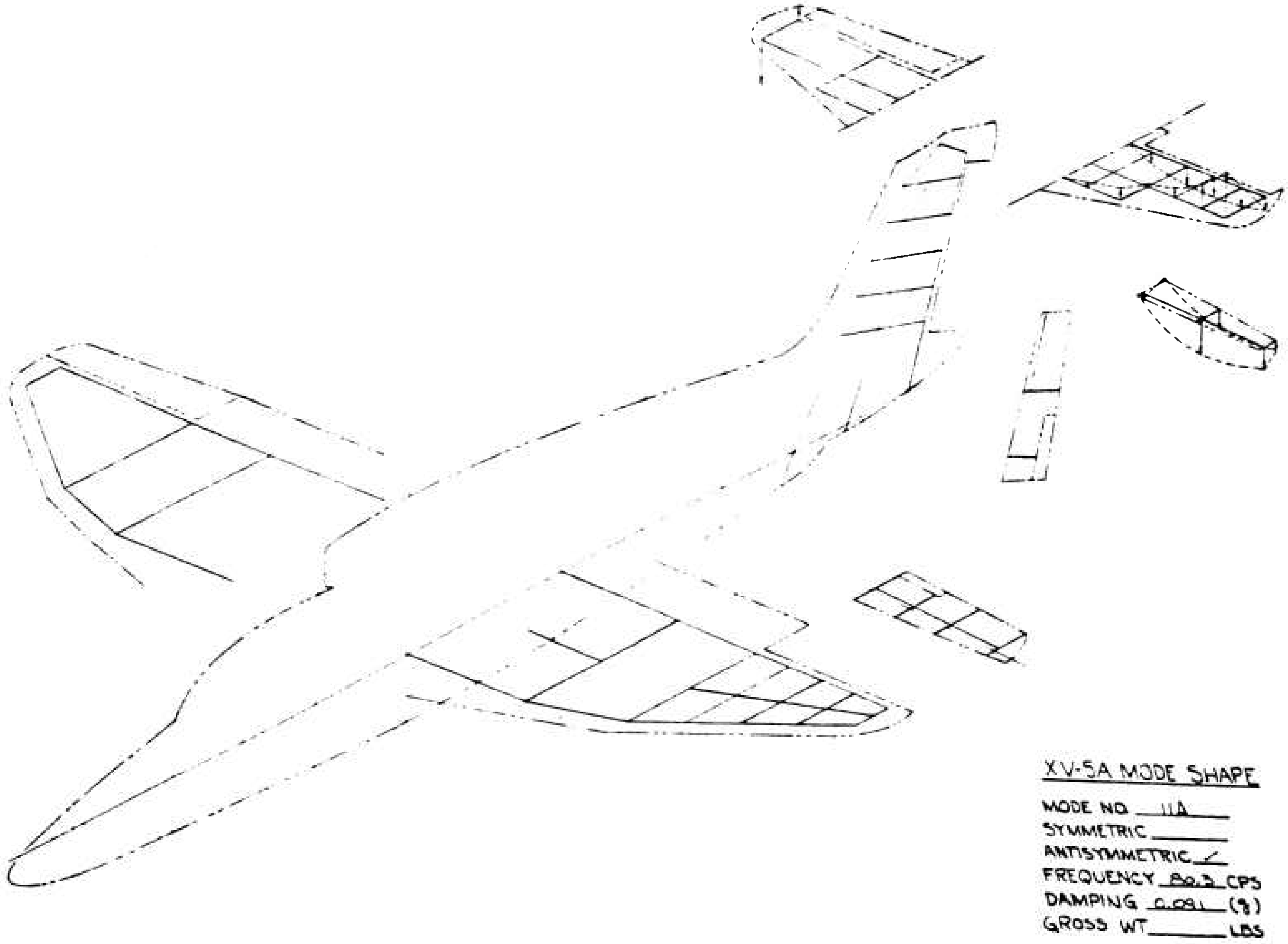


Figure 45 XV-5A Mode Shape - Mode No. 11A

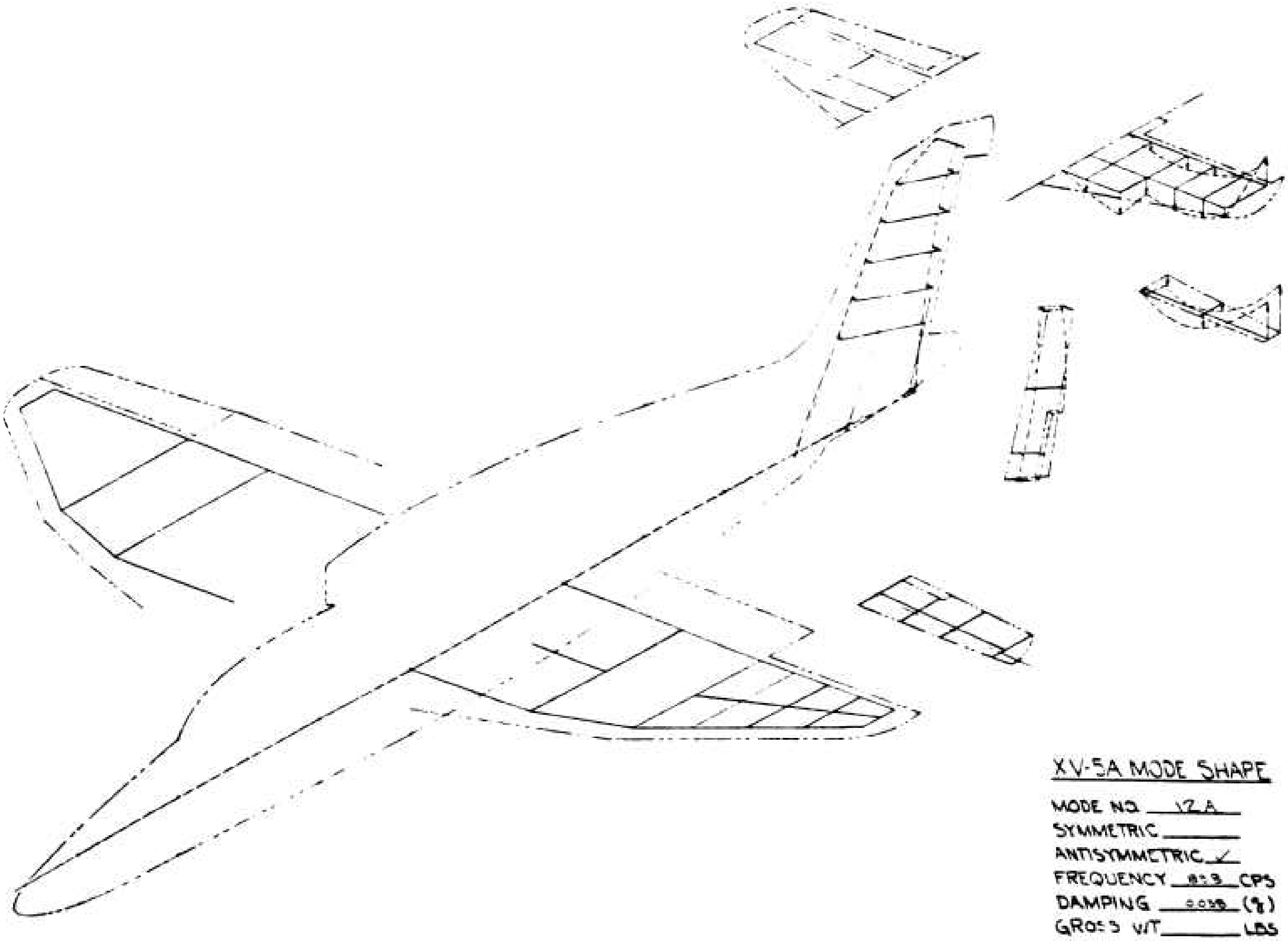


Figure 46 XV-5A Mode Shape - Mode No. 12A

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ADDENDUM A

INTRODUCTION

Flutter considerations of the horizontal tail necessitated a reworking of the horizontal and vertical stabilizers to achieve a higher pitch frequency. Reference 3 presents the results of the preliminary flutter analysis of the empennage. These studies have shown that to meet the 15% flutter margin on the aircraft envelope, a uncoupled pitch frequency of approximately 55 cycles per second was required. The basic ground test of the airplane had shown this mode to be approximately 37 cycles per second, which was deduced from a combination of experimental and analytical results as discussed in Section 5.0. Accordingly, to check the results of the increased stiffness, a vibration test was conducted on the No. 1 aircraft (S/N 62-505) at EAFB during the period of 1 October, 1964 to 8 October, 1964. Emphasis was placed upon empennage characteristics with general checking of other modes in which doubtful areas existed.

TEST CONFIGURATION AND INSTRUMENTATION

The aircraft configuration utilized for this test consisted of the complete aircraft (No. 1, S/N 62-4505), fueled for a gross wieght condition of approximately 9700 pounds with a c.g. location at F.S. 243.85. The aircraft was aligned in a level flight attitude simulating the CTOL mode, with all controls locked in neutral by means of the appropriate cockpit control. Wing and pitch fans were blocked to their stator blades by means of shock chord. To provide a soft mount the aircraft tires were reflated to 125 psig for the main gear and to 90 psig for the nose gear. The nose gear shock strut was filled with hydraulic fluid with locking bars intalled to eliminate the damping action of the strut.

Shaker equipment consisted of two (2) MB Model PT 112537 exciters with associated equipment. Recording instrumentation was similar to that used during the initial ground vibration test, except that one accelerometer (Endevco Model 2213) was used for modal surveys with one accelerometer used as a fixed reference.

TEST PROCEDURE

In general, the test procedure followed that of the first ground vibration test. Initial frequency sweeps of the empennage were made utilizing the

two shakers at positions noted in Figure 4. Resonances were noted from the resulting response plots and modal surveys of the aircraft were made utilizing pickup locations as noted in Figures 5 through 9 upon establishment of the mode. Final oscillograph records were taken of the fixed instrumentation at the conclusion of the survey for frequency and damping values.

RESULTS AND CONCLUSIONS

Excitation of the aircraft by hand produced the following rigid body aircraft modes:

Pitch	2.67 cps
Vertical Translation	3.70 cps
Yaw	1.67 cps
Roll	1.54 cps
Side Translation	1.40 cps

From these results, it was concluded that aircraft suspension frequencies were adequate in view of the elastic modes determined from the first aircraft shake test.

Since stiffening of the horizontal tail pitch restraint is directly tied to symmetric vibration modes of the horizontal tail, initial emphasis was to find the equivalent modes as measured during the initial ground vibration test. The tail modes were numbered Modes 5, 8 and 10. (See Table 3) and were found to be primarily horizontal tail bending, horizontal tail pitch-torsion and a higher tail mode of primarily bending. The results of the second test showed the following in comparison to the original modes:

	1st TEST		2nd TEST	
	f cps	g	f cps	g
Mode 5	31.3	0.031	33.2	0.106
Mode 8	55.9	0.033	63.6	0.082
Mode 10	90.3	0.031	98.3	0.058

These modes are shown in Figures 14, 17 and 19 and are tabulated in Tables 8, 11 and 13 for the first test, whereas the results of the second test are shown in Tables 27, 28 and 29, with pictorial views shown in Figures 42, 43 and 44. Comparison of the modes show that although mode shapes are similar, frequencies have increased due to the stiffening. Neglecting differences between the two airplanes which might explain the

fifth mode frequencies, it was concluded that the second set of modes do actually represent the stiffening effect. As previously, a true uncoupled pitch mode was not readily determined. In order to determine the uncoupled pitch mode frequency, calculations were performed, on a modal coupling basis and correlated to the experimental results. These results indicate that an uncoupled pitch frequency of 47 cycles per second in turn coupled with a first bending mode (calculated) of 40.5 cycles per second and a first torsional mode (calculated) of 81.6 cycles per second, yielded as the first and second coupled frequencies 33+ and 63 + cycles per second respectively, which is in good agreement with the experimental results. The third coupled mode (calculated) yielded approximately 127 + cycles per second, whereas the third experimental proved to be 98.3 cycles per second. This was felt to be insignificant in that the flutter mode of concern was the pitch-torsion mode. The technique of modal coupling yields progressively poorer results for the higher modes.

The antisymmetric vibration test showed that the stiffening also played a part in changing the torsional characteristics of the horizontal stabilizer. The initial mode indicated a frequency of 72.9 cycles per second (shown in Figure 30 and Table 24) whereas the stiffening raised this to 80.3 cycles per second. The latter mode is tabulated in Table 30 and a pictorial view is shown in Figure 45.

Figure 46 depicts a higher antisymmetric bending mode of 89.8 cps per second with the mode shape tabulated in Table 31. This mode had been noted at approximately 77 cycles per second in the initial test, but had not been surveyed due to the relative unimportance of the mode.

Comparison of several modes taken during this second ground test with those obtained during the first ground test indicated no appreciable change due to suspension system restraints i.e. effects of spring-mounted platforms versus deflated gear. Difference in airplanes, that is in stiffness and/or weight were neglected in evaluating this effect.

TABLE 27

SYMMETRIC MODE SHAPE
MODE 5A
f = 33.2 cps g = 0.106

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	–	LH-1	0.6458	F-1	–	LA-1	–	LE-1	1.0000
LW-2	–	LH-2	0.9667	F-2	–	LA-2	–	LE-2	1.0000
LW-3	–	LH-3	0.4167	F-3	–	LA-3	–	LE-3	0.8625
LW-4	–	LH-4	0.6667	F-4	–	LA-4	–	LE-4	0.8542
LW-5	–	LH-5	0.2083	F-5	–	LA-5	–	LE-5	0.5917
LW-6	–	LH-6	0.4042	F-6	0.0092	LA-6	–	LE-6	0.5625
LW-7	–	LH-7	$\bar{0}.0521$	F-7	0.0154	LA-7	–	LE-7	0.3458
LW-8	–	LH-8	0.0250	F-8	0.0238	LA-8	–	LE-8	0.3167
LW-9	–	LH-9	0.1792	F-9	0.0325	LA-9	–	LE-9	0.1250
LW-10	–	LH-10	$\bar{0}.1250$	F-10	$\bar{0}.0658$	LA-10	–	LE-10	0.1000
LW-11	–	LH-11	0.0417	Wing Fan		LA-11	–	LE-11	0.0625
LW-12	–	LH-12	$\bar{0}.1375$	Position	Vert. Defl. + Up	LA-12	–	LE-12	0.0708
LW-13	–	LH-13	$\bar{0}.0417$						
LW-14	–	LH-19	$\bar{0}.0583$	LWF-1	–				
LW-15	–	LH-20	$\bar{0}.1083$	LWF-2	–				
LW-16	–		F & A Defl.	LWF-3	–				
LW-17	–		+ Aft.	LWF-4	–				
LW-18	–	LH-14	0.1925	Pitch Fan					
LW-19	–	LH-15	0.1925	Position	Vert. Defl. + Up				
LW-20	–	LH-16	0.1925						
LW-21	–	LH-17	0.1925	NF-1	–				
LW-22	–	LH-18	0.1925						
LW-23	–								

TABLE 28

SYMMETRIC MODE SHAPE
MODE 8A
$f = 63.6$ cps $g = 0.082$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	—	LH-1	1.0000	F-1	$\bar{0}.0130$	LA-1	—	LE-1	0.4300
LW-2	—	LH-2	0.5200	F-2	0.0070	LA-2	—	LE-2	0.7300
LW-3	—	LH-3	0.6400	F-3	$\bar{0}.0090$	LA-3	—	LE-3	0.2000
LW-4	—	LH-4	0.0700	F-4	$\bar{0}.0050$	LA-4	—	LE-4	0.4200
LW-5	—	LH-5	0.3200	F-5	0.0080	LA-5	—	LE-5	$\bar{0}.2000$
LW-6	—	LH-6	$\bar{0}.2800$	F-6	0.0070	LA-6	—	LE-6	$\bar{0}.1400$
LW-7	—	LH-7	0.4700	F-7	$\bar{0}.0050$	LA-7	—	LE-7	$\bar{0}.5200$
LW-8	—	LH-8	0.1150	F-8	$\bar{0}.0240$	LA-8	—	LE-8	$\bar{0}.5700$
LW-9	—	LH-9	$\bar{0}.4700$	F-9	$\bar{0}.0350$	LA-9	—	LE-9	$\bar{0}.8000$
LW-10	—	LH-10	0.3500	F-10	0.0300	LA-10	—	LE-10	$\bar{0}.8700$
LW-11	—	LH-11	$\bar{0}.5500$	Wing Fan		LA-11	—	LE-11	$\bar{0}.7100$
LW-12	—	LH-12	0.2900	Position	Vert. Defl. + Up	LA-12	—	LE-12	$\bar{0}.7300$
LW-13	—	LH-13	$\bar{0}.5700$						
LW-14	—	LH-19	0.0600	LWF-1	—				
LW-15	—	LH-20	0.0530	LWF-2	—				
LW-16	—		F & A Defl.	LWF-3	—				
LW-17	—		+ Aft	LWF-4	—				
LW-18	—	LH-14	—	Pitch Fan					
LW-19	—	LH-15	—	Position	Vert. Defl. + Up				
LW-20	—	LH-16	—						
LW-21	—	LH-17	—	NF-1	—				
LW-22	—	LH-18	—						
LW-23	—								

TABLE 29

SYMMETRIC MODE SHAPE
MODE 10A
f = 98.3 cps g = 0.058

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	–	LH-1	$\bar{0}.6613$	F-1	–	LA-1	–	LE-1	0.3871
LW-2	–	LH-2	0.2645	F-2	–	LA-2	–	LE-2	0.7903
LW-3	–	LH-3	$\bar{0}.4452$	F-3	–	LA-3	–	LE-3	0.6194
LW-4	–	LH-4	0.0742	F-4	–	LA-4	–	LE-4	1.0000
LW-5	–	LH-5	$\bar{0}.2742$	F-5	–	LA-5	–	LE-5	0.5387
LW-6	–	LH-6	$\bar{0}.0548$	F-6	–	LA-6	–	LE-6	0.7484
LW-7	–	LH-7	$\bar{0}.1935$	F-7	–	LA-7	–	LE-7	0.0000
LW-8	–	LH-8	$\bar{0}.1387$	F-8	–	LA-8	–	LE-8	0.1000
LW-9	–	LH-9	$\bar{0}.1161$	F-9	–	LA-9	–	LE-9	$\bar{0}.4194$
LW-10	–	LH-10	$\bar{0}.0645$	F-10	–	LA-10	–	LE-10	$\bar{0}.6774$
LW-11	–	LH-11	$\bar{0}.1548$	Wing Fan		LA-11	–	LE-11	$\bar{0}.2613$
LW-12	–	LH-12	0.0516	Position	Vert. Defl. + Up	LA-12	–	LE-12	$\bar{0}.5677$
LW-13	–	LH-13	$\bar{0}.1677$						
LW-14	–	LH-19	$\bar{0}.0597$	LWF-1	–				
LW-15	–	LH-20	0.0226	LWF-2	–				
LW-16	–		F & A Defl. + Aft	LWF-3	–				
LW-17	–			LWF-4	–				
LW-18	–	LH-14	–	Pitch Fan					
LW-19	–	LH-15	–	Position	Vert. Defl. + Up				
LW-20	–	LH-16	–						
LW-21	–	LH-17	–	NF-1	–				
LW-22	–	LH-18	–						
LW-23	–								

TABLE 30

ANTISYMMETRIC MODE SHAPE
MODE 11A
f = 80.3 cps g = 0.091

Wing		Horiz. Stab.		Vert. Stab.	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	–	LH-1	1.0000	V-1	–
LW-2	–	LH-2	$\bar{0}.2805$	V-2	–
LW-3	–	LH-3	0.5366	V-3	–
LW-4	–	LH-4	$\bar{0}.4122$	V-4	–
LW-5	–	LH-5	0.2317	V-5	–
LW-6	–	LH-6	$\bar{0}.4634$	V-6	–
LW-7	–	LH-7	0.2707	V-7	–
LW-8	–	LH-8	0.0732	V-8	–
LW-9	–	LH-9	$\bar{0}.4183$	V-9	–
LW-10	–	LH-10	0.1341	V-10	–
LW-11	–	LH-11	$\bar{0}.2610$	V-11	–
LW-12	–	LH-19	0.0220	V-12	–
LW-13	–		Lat. Defl. + Left	V-13	–
LW-14	–			V-14	–
LW-15		LH-12	$\bar{0}.0329$	V-15	–
LW-16		LH-13	0.0307	V-16	–
LW-17		LH-20	$\bar{0}.0095$	V-17	–
LW-18			F & A Defl. + Aft	F-25	–
LW-19	–			F-26	–
LW-20	–	LH-14	–	F-27	–
LW-21	–	LH-15	–		
LW-22	–	LH-16	–		
LW-23	–	LH-17	–		
	F & A Defl. + Aft	LH-18	–		
LW-24	–				
LW-25	–				
LW-26	–				
LW-27	–				

Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Lat. Defl. + Left	Ang. Defl. X10[3]*	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
F-11-12	–	–	LA-1	–	LE-1	$\bar{0}.4561$	R-1	0.0161
F-13-14	–	–	LA-2	–	LE-2	$\bar{0}.2341$	R-2	0.0132
F-15-16	–	–	LA-3	–	LE-3	$\bar{0}.7634$	R-3	$\bar{0}.0080$
F-17-18	–	–	LA-4	–	LE-4	$\bar{0}.4634$	R-4	$\bar{0}.0073$
F-19-20	–	–	LA-5	–	LE-5	$\bar{0}.8805$	R-5	$\bar{0}.0176$
F-21-22	–	–	LA-6	–	LE-6	$\bar{0}.5220$	R-6	$\bar{0}.0161$
F-23-24	–	–	LA-7	–	LE-7	$\bar{0}.7122$	R-7	$\bar{0}.0190$
F-25-30	–	–	LA-8	–	LE-8	$\bar{0}.3878$	R-8	$\bar{0}.0168$
F-26-31	–	–	LA-9	–	LE-9	$\bar{0}.3707$	R-9	$\bar{0}.0176$
F-27-32	–	–	LA-10	–	LE-10	$\bar{0}.1024$	R-10	$\bar{0}.0168$
	Wing Fan		LA-11	–	LE-11	$\bar{0}.1317$	R-11	$\bar{0}.0088$
	Position	Vert. Defl. + Up	LA-12	–	LE-12	0.0780	R-12	$\bar{0}.0058$
	LWF-1	–						
	LWF-2	–						
	LWF-3	–						
	LWF-4	–						

* Left Wing Down

TABLE 31

ANTISYMMETRIC MODE SHAPE
MODE 12A
f = 89.8 cps g = 0.038

Wing Position	Vert. Defl. + Up
LW-1	–
LW-2	–
LW-3	–
LW-4	–
LW-5	–
LW-6	–
LW-7	–
LW-8	–
LW-9	–
LW-10	–
LW-11	–
LW-12	–
LW-13	–
LW-14	–
LW-15	–
LW-16	–
LW-17	–
LW-18	–
LW-19	–
LW-20	–
LW-21	–
LW-22	–
LW-23	–
	F & A Defl. + Aft
LW-24	–
LW-25	–
LW-26	–
LW-27	–

Horiz. Stab. Position	Vert. Defl. + Up
LH-1	$\bar{0}.1897$
LH-2	0.6092
LH-3	$\bar{0}.3908$
LH-4	0.0087
LH-5	$\bar{0}.4425$
LH-6	$\bar{0}.2126$
LH-7	$\bar{0}.4770$
LH-8	$\bar{0}.3678$
LH-9	$\bar{0}.2931$
LH-10	$\bar{0}.2713$
LH-11	$\bar{0}.2069$
LH-12	$\bar{0}.2299$
	Lat. Defl. + Left
LH-12	0.1804
LH-13	0.1322
LH-20	0.1552
	F & A Defl. + Aft
LH-14	0.0057
LH-15	0.0115
LH-16	0.0161
LH-17	0.0218
LH-18	0.0264

Vert. Stab. Position	Lat. Defl. + Left
V-1	$\bar{0}.1126$
V-2	$\bar{0}.1011$
V-3	$\bar{0}.0575$
V-4	$\bar{0}.1483$
V-5	$\bar{0}.1322$
V-6	$\bar{0}.1644$
V-7	$\bar{0}.2046$
V-8	$\bar{0}.1632$
V-9	$\bar{0}.2529$
V-10	$\bar{0}.1425$
V-11	$\bar{0}.2471$
V-12	$\bar{0}.1897$
V-13	$\bar{0}.0115$
V-14	$\bar{0}.1425$
V-15	$\bar{0}.1678$
V-16	$\bar{0}.1759$
V-17	$\bar{0}.1494$
F-25	0.0092
F-26	0.0483
F-27	0.1057

Fuselage (WL 100) Position	Lat. Defl. + Left	Ang. Defl. X10³*
F-11-12	–	–
F-13-14	–	–
F-15-16	–	–
F-17-18	–	0.6144
F-19-20	$\bar{0}.0261$	1.3644
F-21-22	$\bar{0}.0321$	1.1903
F-23-24	$\bar{0}.0285$	0.7961
F-25-30	0.0092	$\bar{1}.1639$
F-26-31	0.0491	$\bar{3}.6842$
F-27-32	0.1117	$\bar{8}.4755$

Wing Fan Position	Vert. Defl. + Up
LWF-1	–
LWF-2	–
LWF-3	–
LWF-4	–

Aileron Position	Vert. Defl. + Up
LA-1	–
LA-2	–
LA-3	–
LA-4	–
LA-5	–
LA-6	–
LA-7	–
LA-8	–
LA-9	–
LA-10	–
LA-11	–
LA-12	–

Elevator Position	Vert. Defl. + Up
LE-1	0.7299
LE-2	1.0000
LE-3	0.5977
LE-4	0.8448
LE-5	0.2184
LE-6	0.3563
LE-7	$\bar{0}.2609$
LE-8	$\bar{0}.1839$
LE-9	$\bar{0}.4138$
LE-10	$\bar{0}.5517$
LE-11	$\bar{0}.1149$
LE-12	$\bar{0}.2253$

Rudder Position	Lat. Defl. + Left
R-1	$\bar{0}.2828$
R-2	$\bar{0}.2356$
R-3	$\bar{0}.0816$
R-4	$\bar{0}.0414$
R-5	0.0804
R-6	0.0989
R-7	0.1356
R-8	0.1322
R-9	0.1264
R-10	0.1333
R-11	0.0874
R-12	0.0770

* Left Wing Down